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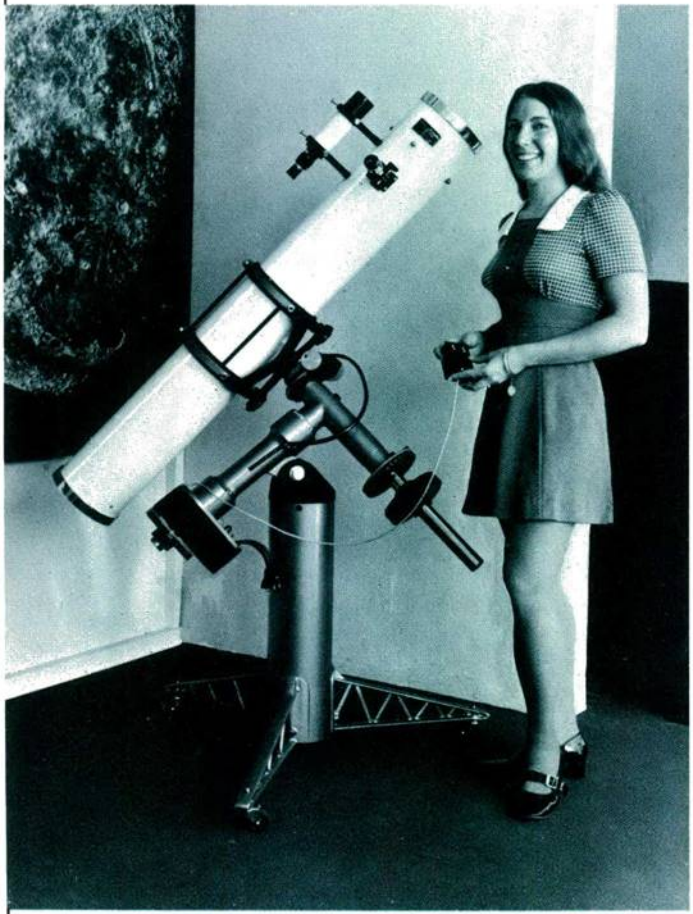

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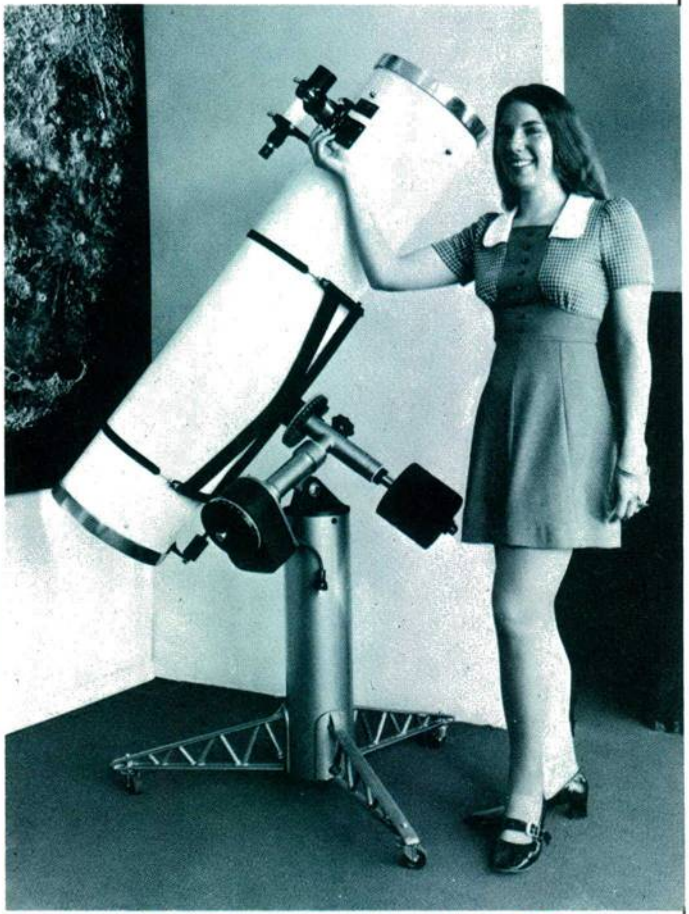

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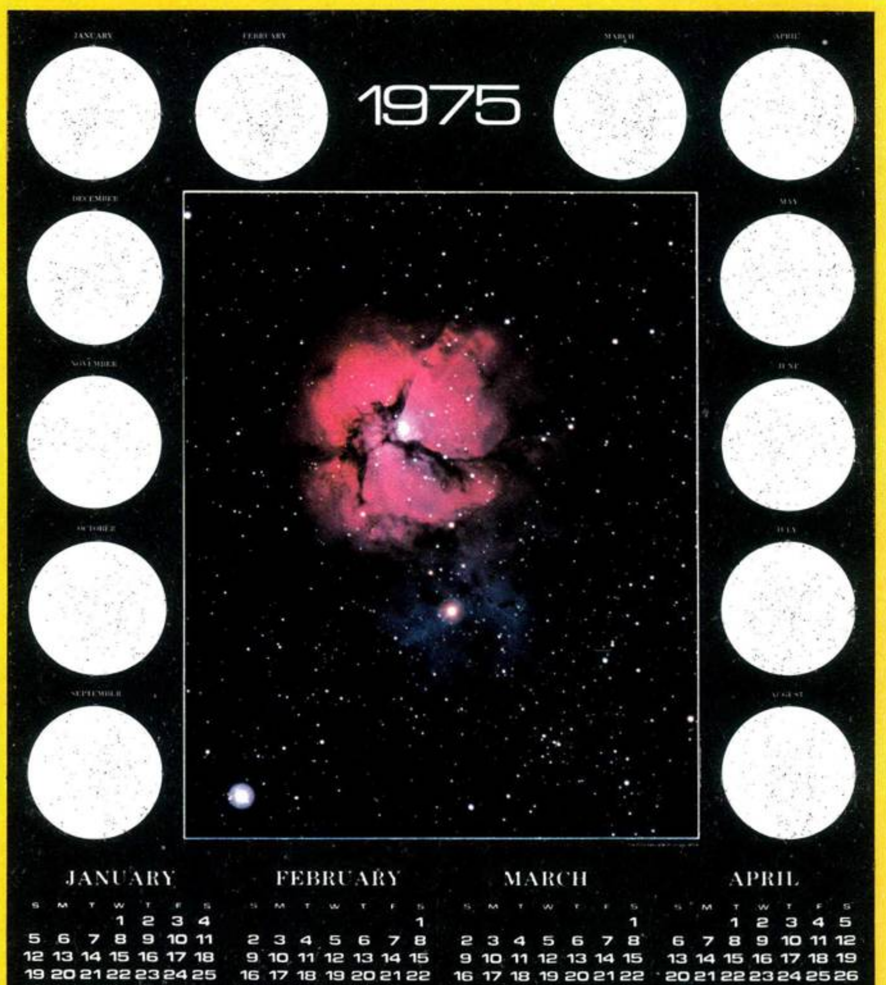

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PUBLISHER'S MEMO

To aid readers in obtaining back issues of ASTRONOMY we have inaugurated a Guide to Back Issues this month in Astro-Mart. We will publish this guide each month and will change it monthly to reflect which issues are available, in short supply or depleted. This guide will be indexed for your convenience.

While we have not yet completed tabulation of the survey in the December issue, one fact is unmistakably clear: ASTRONOMY readers are outstandingly involved with the magazine. We would have been pleased to get 5,000 surveys back — but instead, by the time this issue is mailed to you (Jan. 15, 1975), we will have received well over 10,000 completed questionnaires. (To date we have received 9,000.) This unquestionably spells reader involvement. And I personally thank you for the compliment.

Since many of you are interested in knowing the results of the survey, we will let you know what we learned about you and your interests in future Publisher's Memos.

Many thanks for your enthusiastic response to the minisurvey in the November Publisher's Memo. It appears that the majority of readers would be willing to spend a little more for reprints and posters to insure that we continue to publish them. Color photographs are most in demand with half as many people interested in color artwork. There is very little interest in black and white reprints and posters — which surprises me since black and white can also be quite beautiful. For example, we have a clever way to make black and white photographs look more pictorial and interesting by printing them with two ink colors (instead of just black ink with white paper). Using deep blue ink and a light blue ink we can reproduce a black and white photograph so that fine detail is highlighted and the photographs look more attractive.

Furthermore, there are hundreds of magnificent, spectacular black and white photos from observatories throughout the world that we'd like to make available to you. Kitt Peak National Observatory alone has many brand new photos made with the new 158 inch Mayall telescope — most of which have never been published before. And frankly, I'd like to make some of these photographs available to you.

So, keeping this in mind, are you sure you wouldn't like to buy a set of eight photos (which we'd print in two colors) — each measuring 8-1/2 x 11 inches on heavy gloss paper — for the small sum of $2 per set including first class postage?

The fact is, we'd only have to sell 500 sets to be able to make the photos available to you. And if at least 500 of you write me a letter indicating you're interested in obtaining a set of these photographs, I'll see to it that you are rewarded by letting you have the opportunity to buy these sets before anyone else - even before we place an ad in ASTRONOMY.

So get your pens fired up and let me know right away. Please be sure to include your full name, address and zip code.

'Nuf said.

Sincerely,

Stephen A. Walther

Stephen A. Walther
Publisher

ASTRONOMY

The World's Most Beautiful Astronomy Magazine

February 1975 Vol. 3, No. 2

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Cover

Photograph by Robert Provin

The Orion nebula is among the most photographed objects in the sky — yet each portrait reveals a different aspect of this immense cloud of interstellar dust and gas. Illuminated by hot stars at its core, the nebula engulfs at least 1,000 cubic light-years. The great cloud is thought to be the birthplace of stars, and astronomers believe several hundred brilliant suns will emerge from this stellar incubator during the next several thousand years. Known as M-43, the main nebula is visible to the unaided eye and is a marvelous sight in a telescope as described in this month's Star Dome. However, the detail seen here is beyond the visual sensitivity of the eye. The apparently detached portion of the nebula (below) is known as M-43. For this one hour exposure on GAF 200 film a six inch f/5 Newtonian reflector was used.

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Second class postage paid at Milwaukee, Wisconsin.

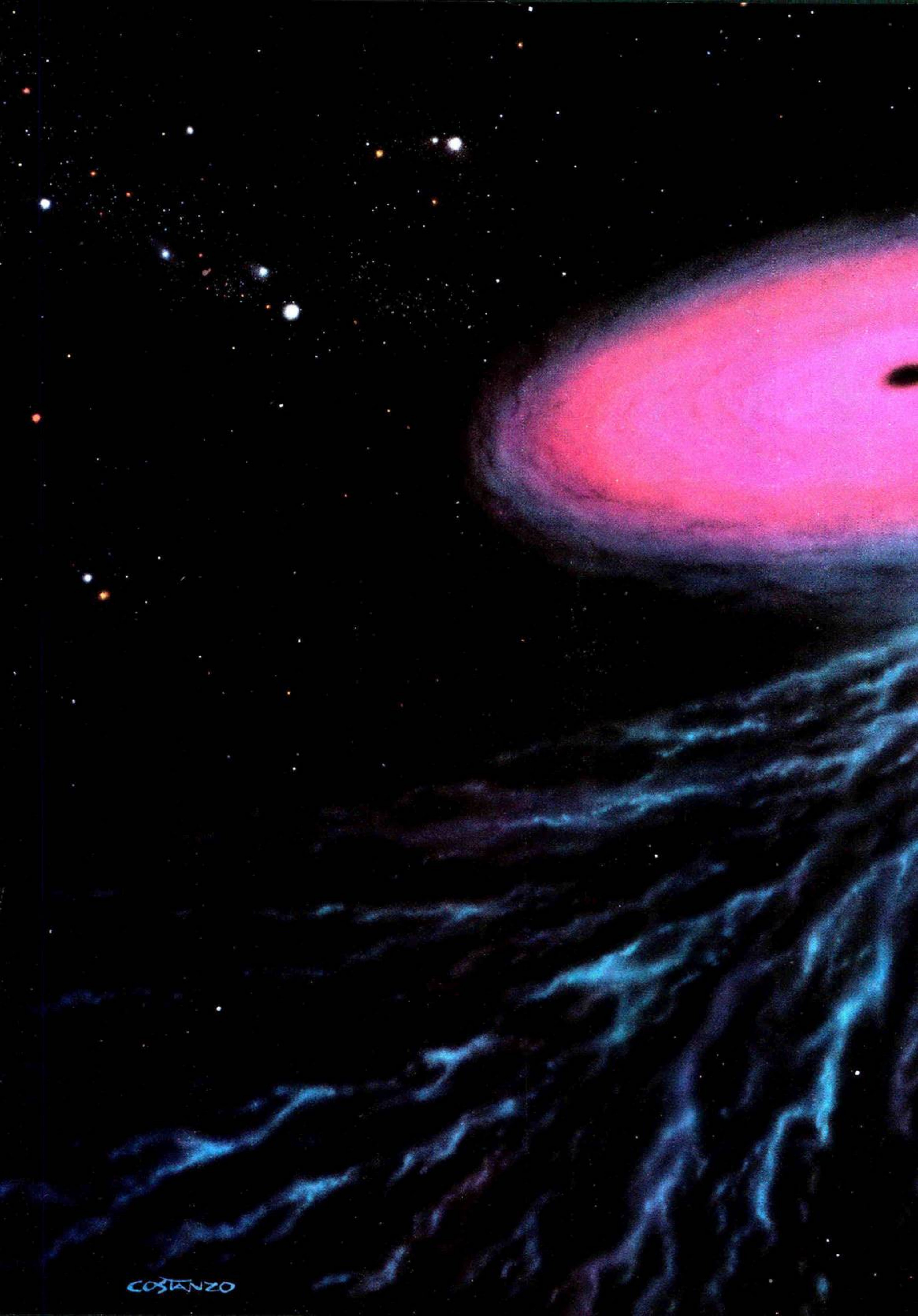
Direct all subscription correspondence, new subscriptions, changes of address and complaints to ASTRONOMY, Circulation Services, 640 North LaSalle Street, 6th Floor, Chicago, Illinois 60610. Allow six to eight weeks for address change to take effect.

Cover price, $1.50. Subscription price: 1 year, $12.00; 2 years, $22.00; 3 years, $30.00. Canada and Mexico: add $3.00 per year. All other foreign: add $6.00 per year.

POSTMASTER: When undeliverable, send form 3579 to publisher.

Typesetting by Grafilm, Inc., Milwaukee, Wisconsin 53210; Separations prepared by American Color Systems, New Berlin, Wisconsin 53005; Printed by E. F. Schmidt Co., Menomonee Falls, Wisconsin 53051.

Due to the limited availability of back issues, new subscriptions must start with the most current month's issue. If you wish to order back issues it is advisable to inquire first before placing an order.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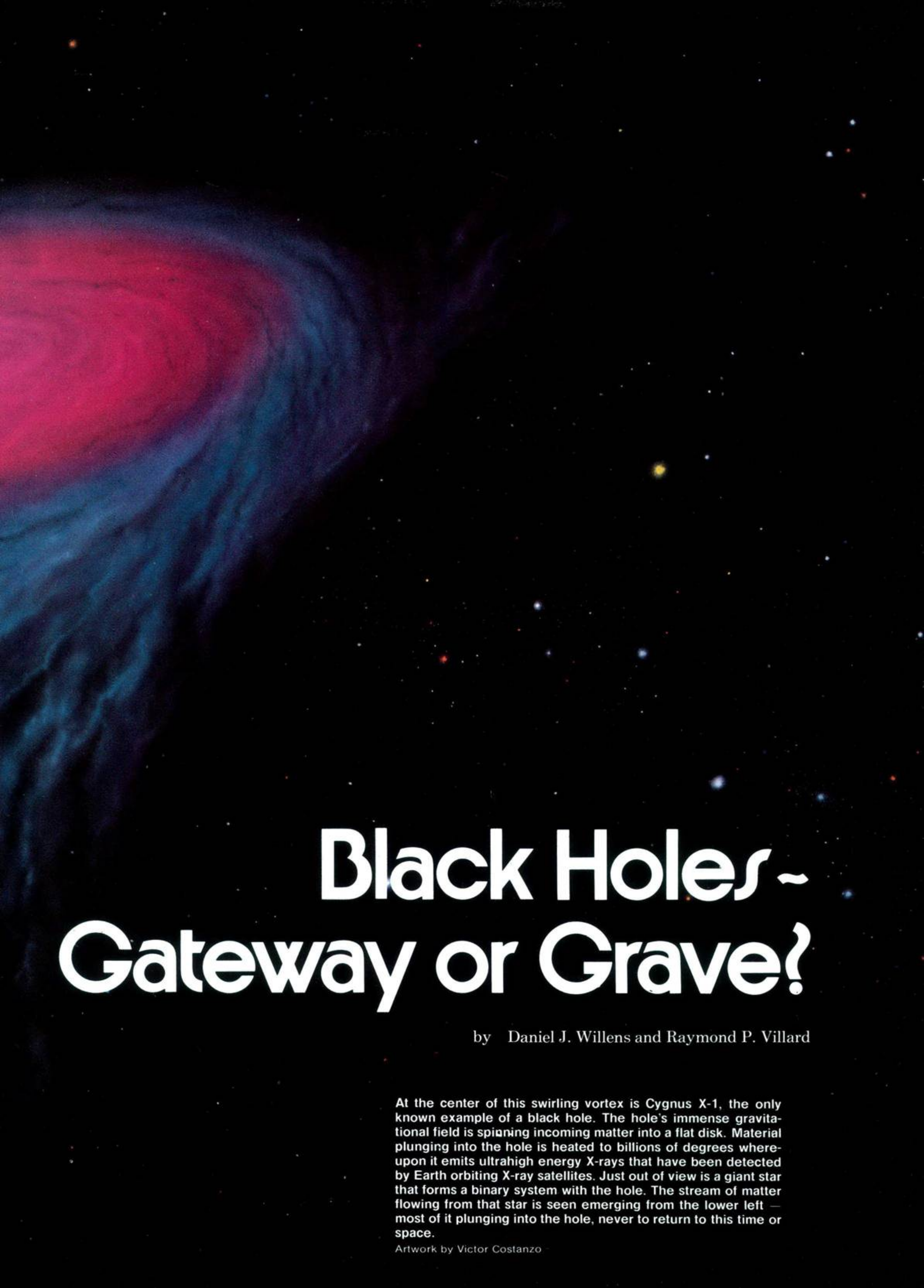


Black Holes – Gateway or Grave?

by Daniel J. Willens and Raymond P. Villard

At the center of this swirling vortex is Cygnus X-1, the only known example of a black hole. The hole's immense gravitational field is spinning incoming matter into a flat disk. Material plunging into the hole is heated to billions of degrees whereupon it emits ultrahigh energy X-rays that have been detected by Earth orbiting X-ray satellites. Just out of view is a giant star that forms a binary system with the hole. The stream of matter flowing from that star is seen emerging from the lower left — most of it plunging into the hole, never to return to this time or space.

Artwork by Victor Costanzo

Picture a star-sprinkled vista of space somewhere in the galaxy. It looks very much like any other interstellar tract except for an area where background stars grow dimmer and dimmer, crowding toward a point where the sky is absolutely black. But not the sooty gray black of terrestrial skies or even the star-speckled black of deep space. This black is perfectly black, where no impinging light ray can ever hope to escape. Here lurks an invisible spider spinning a gravitational web in the deepest imaginable pit among the stars. We call the monster a black hole.

If we could take a backward voyage in time to examine the origin of the mysterious black hole, we would find, some millions or billions of years ago, a star occupying the patch of darkness where the hole is now. Several times more massive than our sun, the star burns with a blinding radiance — ferociously converting hydrogen to helium in the fires of nuclear fusion.

After only a few million years the spendthrift sun exhausts its hydrogen fuel supply. Desperately the star tries substituting the helium "ash" created and stored over past eons. But igniting helium fusion reactions requires temperatures much hotter than for hydrogen. As core temperatures skyrocket to hundreds of millions of degrees the unwary sun can no longer keep a strong gravitational grasp on its outer layers. The star now becomes far more than it ever was before. The hot core balloons the sun to colossal proportions. Like a slowly awakening giant that until now somehow remained dormant, the star grows larger and redder — and deadly. One by one, the inner planets that have obediently orbited their master since their creations are cooked and then consumed as the supergiant reaches its full 500 million mile diameter.

As the helium fires eventually burn out, still heavier elements are created — up to and including iron. But it ends there. Death nears as no forces remain to support the bloated monster. Now the weakest force in the universe — gravity — has the last say.

In a thundering crescendo of light and heat, an inconceivable suicide begins. Energy generated by the swiftly collapsing stellar core drives temperatures into billions of degrees, blasting material violently into space and providing the awesome forge for the creation of elements heavier than iron — elements which will later be among the raw materials for future generations of stars and planets. Meanwhile energy seething from the eruption forms an ever widening wave front that will soon alert beings inhabiting dozens of nearby galaxies. A supernova is created — the death of a star.

Like a forest fire running out of control, the remnants of the star cave inward with increasing fury. As the shrinking sphere approaches Earth's diameter, gravity squeezes atoms tighter and tighter together until the electron shells surrounding every atomic nucleus shatter like a falling house of cards. The vast empty space once separating each nucleus from its family of orbiting electrons now jams with millions of displaced nuclei. The squeeze multiplies ever more powerfully as even electrons and protons crush together, forming neutrons.

The stellar corpse has shriveled to only 20 miles in diameter and now resembles an overgrown atomic nucleus; each supercondensed spoonful of it weighs tens of millions of tons. In some stellar suicides nuclear forces would build up enough strength to halt the wild collapse at this point, allowing the core to live out its existence as a neutron star. But our star's core retained more than three times our sun's mass, and gravitation overwhelms even the tightly packed neutrons. The contraction continues.

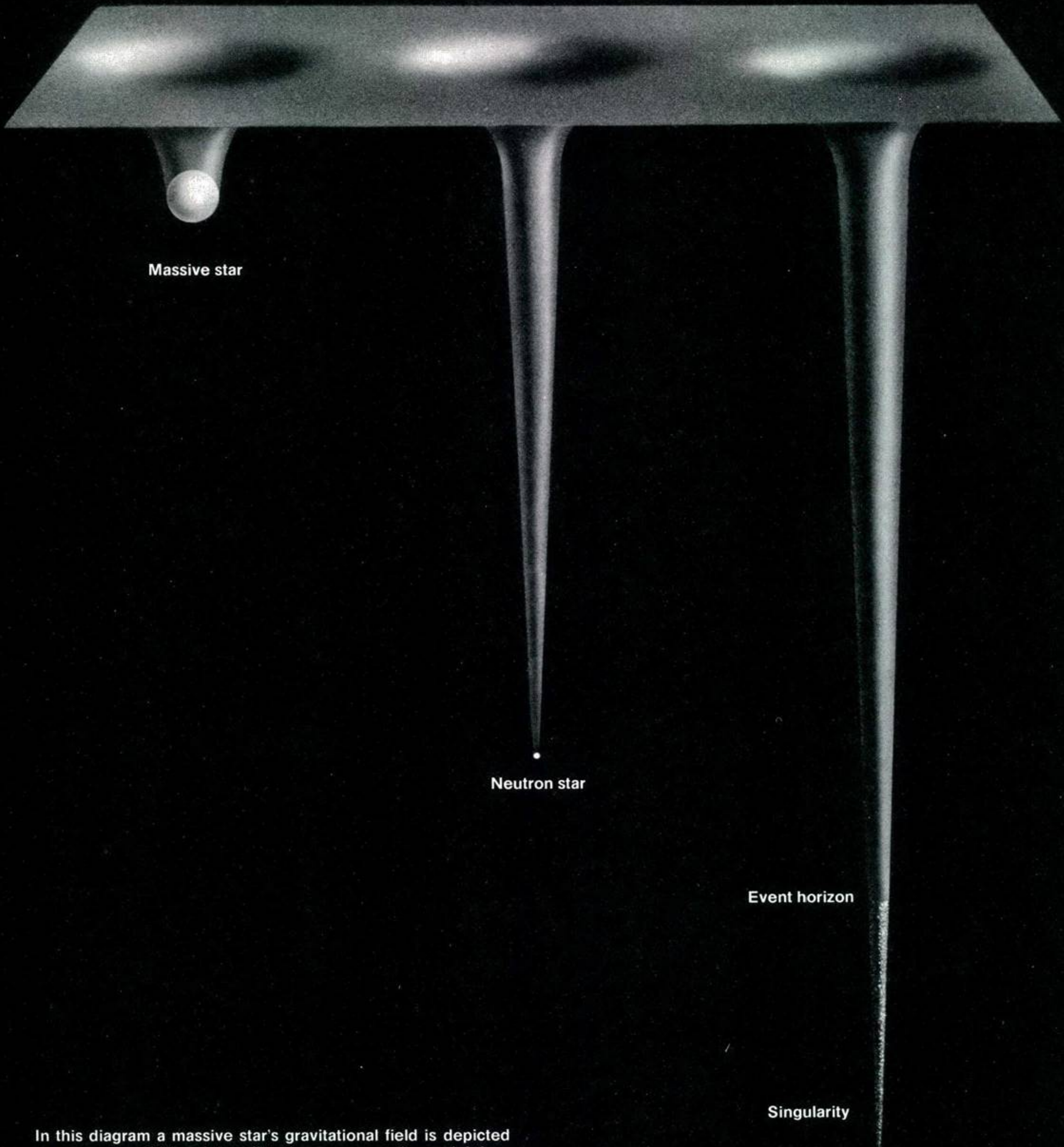
To an outside observer the shrinking star has vanished as abruptly as a snuffed-out candle. To the material universe of three dimensions it manifests itself as nothing but a disembodied gravitational field, a point source of gravity, a black hole.

Incredible as the story of a black hole's birth seems, this scenario is soundly based on modern day astrophysics. Using Einstein's general theory of relativity, physicists Robert Oppenheimer and Hartland Snyder first calculated (in 1939) that sufficiently massive stars could crush themselves out of existence — leaving behind a gravitational whirlpool in empty space.

Any matter or energy falling into this abyss would first pass a distinct point of no return called the "event horizon". Once within this boundary nothing could ever muster enough energy to escape since it would have to travel faster than the speed of light — which is impossible according to modern physics. Arriving at the black hole's center — a stellar grave bluntly called "singularity" — a trapped visitor's molecular, chemical and nuclear makeup would disintegrate into oblivion.

A black hole's gravitational wallop results from immense amounts of matter jammed into an extraordinarily tiny space. (At least three solar masses are required to form the hole in the first place.) Gravity's strength increases dramatically the closer you approach the center of a gravitational field. We calculate gravity's change in force by taking the inverse square of the distance between an object and the field's center. Double your distance and gravity drops to 1/4 its power; get twice as close and gravity quadruples.

For example, we sit comfortably on Earth's surface never getting any closer than roughly 4,000 miles to our planet's center. But by shrinking Earth so that we are twice as close to its center (2,000 miles), gravity's pull increases four times. Com-



In this diagram a massive star's gravitational field is depicted as a warp, or whirlpool, in a flat plane representing weightless space. As the star's radius shrinks to the size of a white dwarf, gravity's strength increases and the whirlpool deepens. In reaching the star's surface a visitor would now have to fall much farther into its gravitational field than he would if the star remained normal size, and would likewise need more energy to climb back out of the deepened gravity-crater. As the star further contracts into a black hole, the gravity field intensifies until anything plunging into the bottom of the funnel — past the event horizon — can never build up enough speed to ascend back into space.

Diagram by Victor Costanzo

press Earth to a radius of 1,000 miles and gravity jumps to 16 times its former power (your weight at this point is approaching two tons); 30 miles, 16,000 times; 1 mile, 16 million times. Squeezing Earth to a ping-pong ball size circumference (intense gravitational distortion of space now makes Earth's radius unknown) of 2.196 inches — the point where anything would have to travel the speed of light (186,000 miles per second) to escape — would transform our world into a small scale black hole.

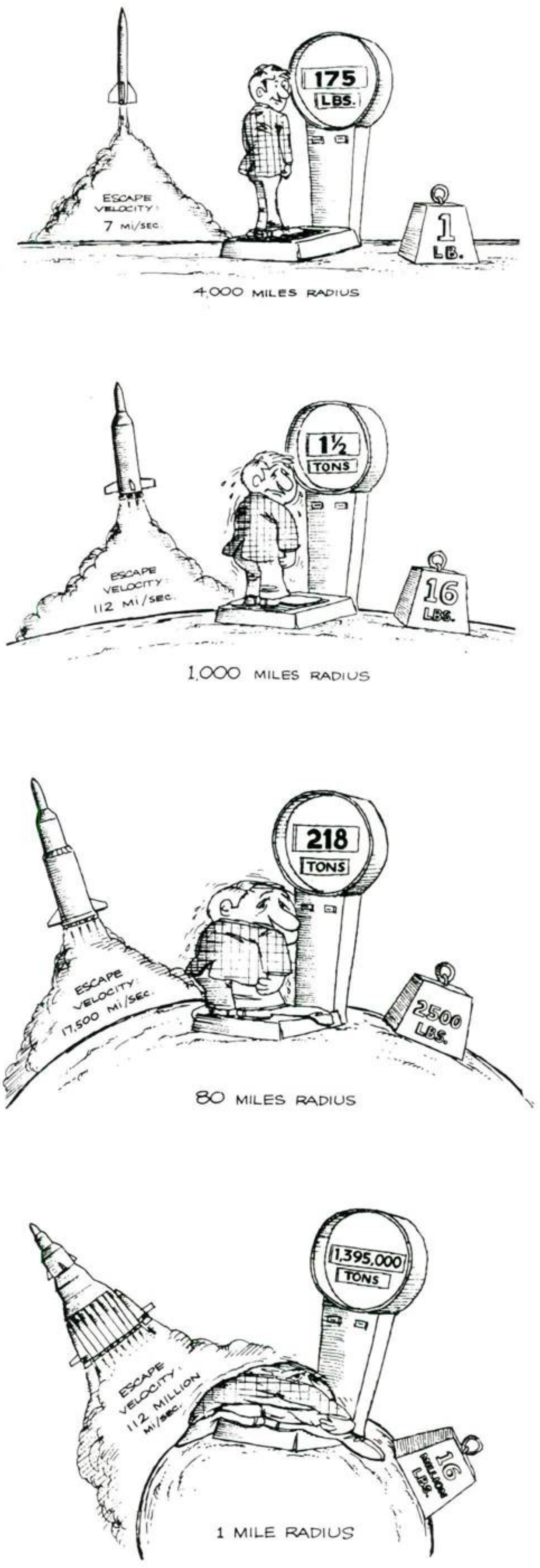
In 1939 black holes were considered strictly hypothetical beasts, sounding more like they belonged in science fiction magazines than astrophysical journals. Only in the past decade have sounding rockets and satellites given astronomers the potential to search for black holes by sending instruments beyond Earth's obscuring atmosphere.

But how do you track down a star's ghost? What is to be seen of a bottomless pit greedily swallowing matter and energy? Mathematical models of black holes say that matter should emit a sort of electromagnetic death cry as it plummets into the enormous gravitational vortex. Matter colliding and compressing in the dizzying plunge may heat up to 100 million degrees, spewing out intense X-rays.

Several 1971 satellite observations of a powerful X-ray source in the constellation Cygnus have been interpreted as the first trickle of evidence for black holes. A superhot blue giant star (at least 20 times heavier than our sun) orbited by a small unseen companion inhabits this unusual region labeled Cygnus X-1. Astronomers believe that gases flow along a fiery bridge leading from the massive star to its invisible satellite where material then superheats and sprays back out to space as X-rays.

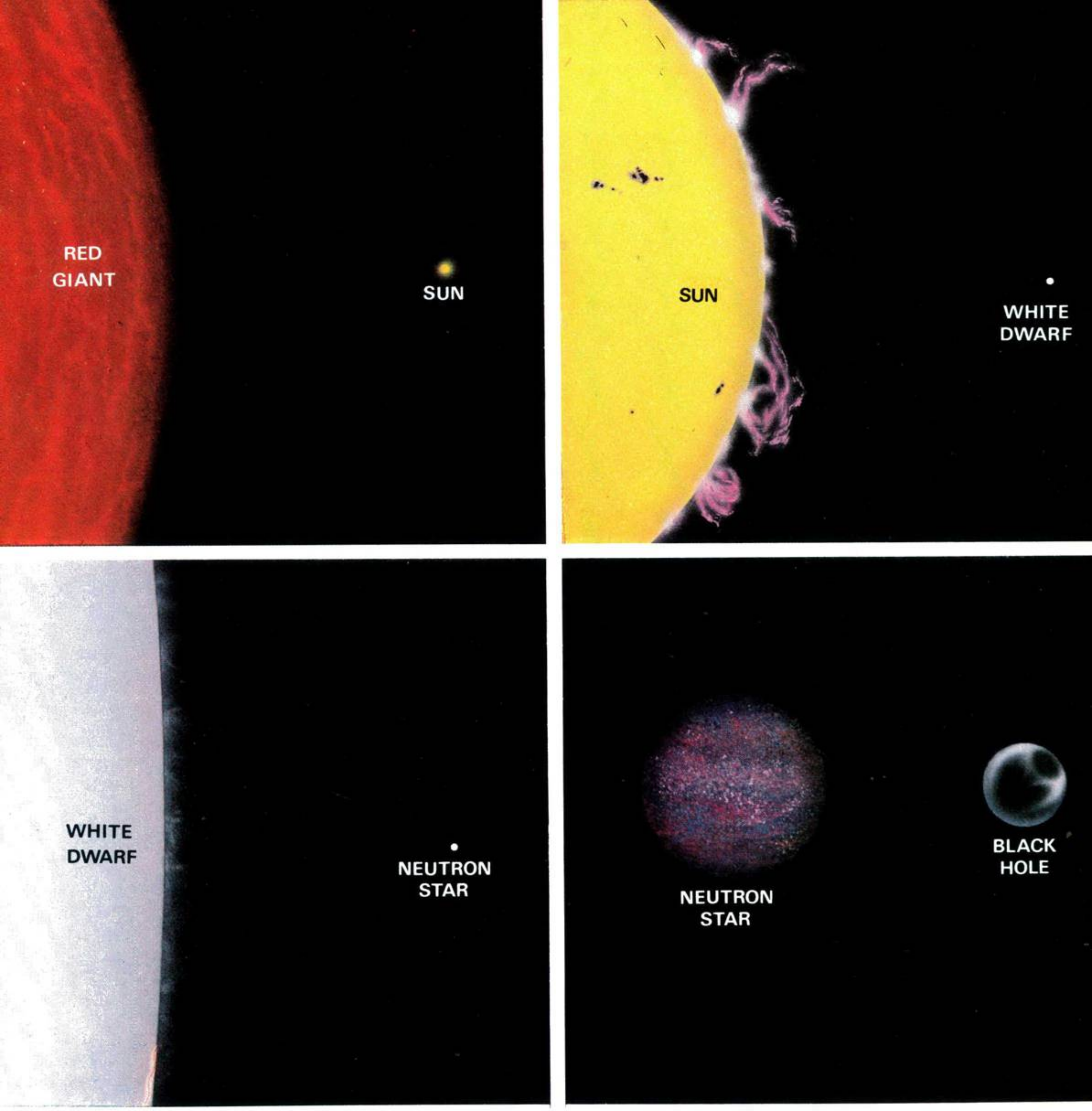
Although white dwarfs and neutron stars are also powerful enough to tug at the blue giant like a space age David taking on Goliath, Cygnus' outpouring X-rays have the special signature of a black hole. Like sputtering flashes from a string of exploding firecrackers, X-rays escaping from the chaos of matter crashing into a black hole should wildly fluctuate in intensity. In contrast, X-rays from pulsars (pulsars are neutron stars) always reach Earth in bursts as steady as light from a rotating airport beacon.

In studying data from observations of Cygnus X-1, Princeton University astronomer Remo J. Ruffini discovered what he calls a "bursting spectrum". Within the spectrum lies an intensive burst of X-rays which, when examined closely, reveal three peaks of energy, each five milliseconds apart.



If some magical power could squeeze Earth increasingly smaller (without losing mass), the force of gravity would skyrocket as Earth's surface draws ever closer to the planet's gravitational center. Gravity's strength increases as the inverse square of the radius separating our doomed experimental subject from Earth's center. When the escape velocity required for leaving Earth passes 186,000 miles per second (light's velocity), our world would be defined as a black hole.

Diagram by Victor Costanzo



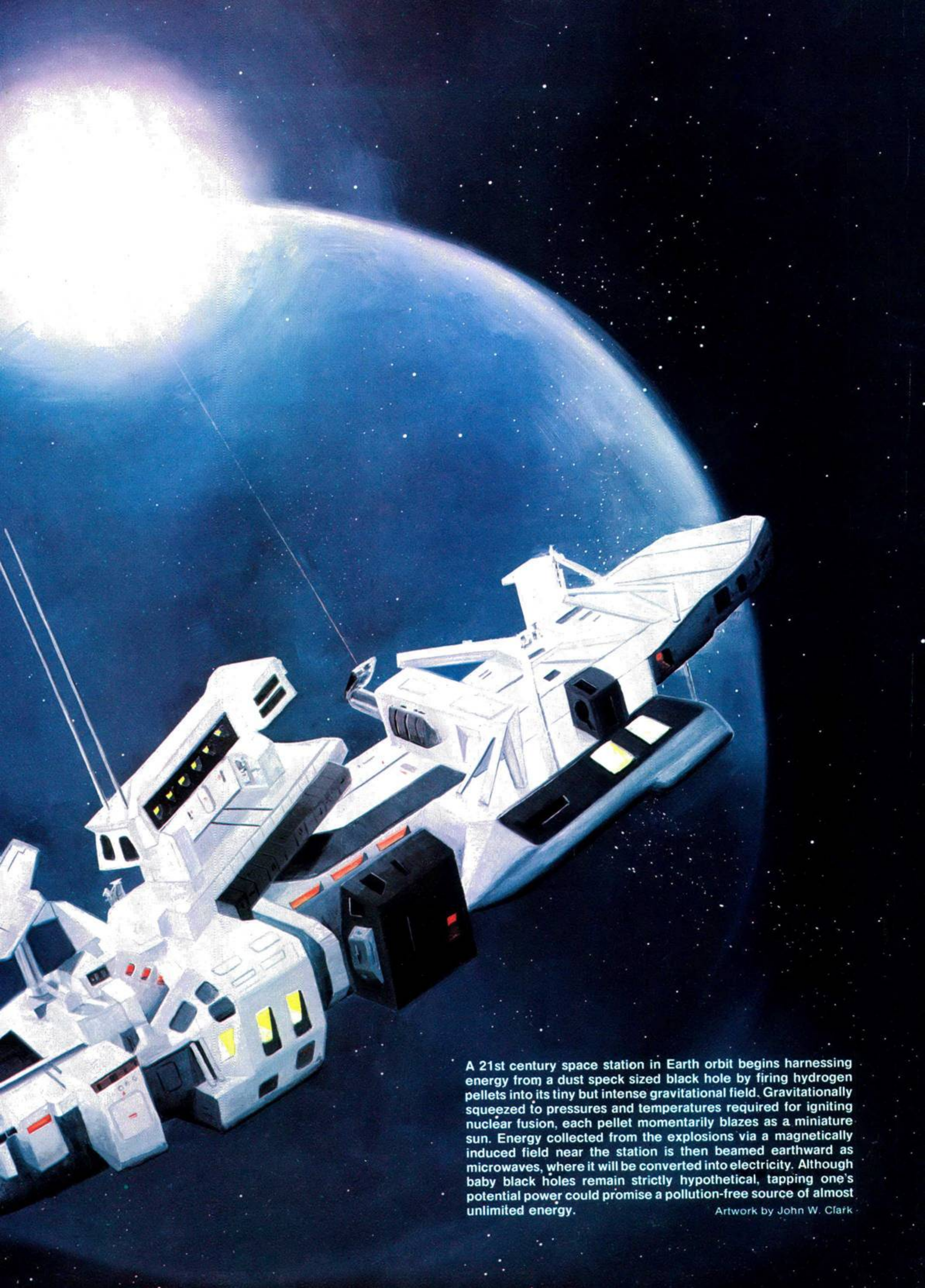
Artwork by Victor Costanzo

The vast range of sizes among stars are compared to the theoretical minimum size for a black hole. (Miniholes are postulated but their existence is unproved.) It is likely that a massive star will be a red giant at one stage in its life and later collapse to a black hole after it commits involuntary suicide in a supernova explosion.

This agrees with a theoretical model where a small clump of matter would emit X-rays as it swirled into a death-spiral orbit of a black hole. Five milliseconds, it turns out, is the period of the nearest stable orbit around a black hole 10 times the sun's mass.

More recent observations indicate that a black hole may be hiding in the Small Magellanic Cloud, and accompanying two more supergiants cryptically called 2U 1700-37 and 2U 0900-40. Typically, the holes could weigh 3 to 50 times more than our sun and range in circumference from 40 to 600 miles.

However, mammoth black holes more massive than 100 million of our suns may lurk at the galaxy's center according to Donald Lynden-Bell of the University of Cambridge. Catastrophic explosions at the centers of other galaxies hint that super-black holes are being born out of violent deaths among the closely packed stars populating each nucleus. As the growing monster sucks in surrounding gas and



A 21st century space station in Earth orbit begins harnessing energy from a dust speck sized black hole by firing hydrogen pellets into its tiny but intense gravitational field. Gravitationally squeezed to pressures and temperatures required for igniting nuclear fusion, each pellet momentarily blazes as a miniature sun. Energy collected from the explosions via a magnetically induced field near the station is then beamed earthward as microwaves, where it will be converted into electricity. Although baby black holes remain strictly hypothetical, tapping one's potential power could promise a pollution-free source of almost unlimited energy.

Artwork by John W. Clark

dust it should belch out infrared radiation and gravity waves. Several bright infrared sources have been detected at the heart of our own galaxy, although astronomers have not been able to rule out other causes for the strange emissions.

Some theorists speculate that such a giant hole's concentrated gravity might be attenuating light from distant objects, making them appear redder than they really are.

Scientists interpret a tiny shift in the color (or frequency) of a star's light as an indication that the star is moving closer to us or farther away. Just as we notice a drop in the pitch of an ambulance's siren as it speeds away, light from a receding star appears to be coming from a lower "pitch" in the spectrum — the red end. Both the siren's sound waves and the star's light waves are stretched as the moving object pulls them away with it. Alternately, approaching objects squeeze light waves, shortening their frequency and thus shifting their color toward the spectrum's blue end.

GUEST OPINION

Why Study Black Holes?

by Kip S. Thorne

Most astrophysicists believe that black holes are a fundamental aspect of our universe. But who needs black holes anyway? Of what practical use is such knowledge?

During the next century or two there will be little practical application for our understanding of black holes. But let's look at it this way: Society supports some aspects of science solely on the basis of their cultural value just as society supports music and art on the same basis. Cosmology and black hole astronomy are perfect examples of this. After all, what is of greater cultural value than the understanding of man's place in the universe and the nature of the universe around him? We are reaching out and beginning to explore the solar system. Soon stars will be within our grasp. What we are learning today will ultimately be of value to future generations. Astronomers and those who are fascinated by astronomy must not be ashamed to say that much of it has no immediate practical application.

Dr. Kip Thorne is an internationally recognized authority on black hole astrophysics. The above comments are an excerpt from an interview conducted by editor Terence Dickinson. For more of Thorne's comments, see the March and April 1974 issues.

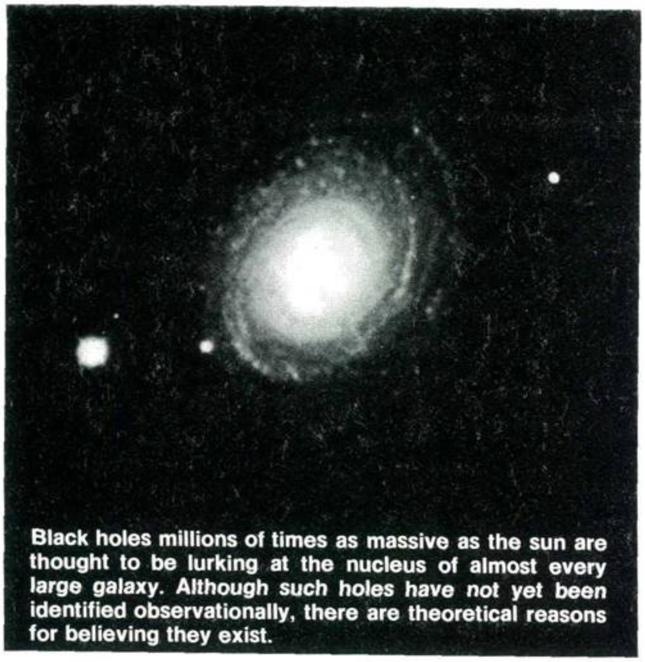
All observable galaxies beyond our very nearest neighbors have so-called "redshifts", telling us that they are flying away from us and that the universe is expanding. Those mysteriously brilliant starlike objects called quasars are extremely redshifted, indicating that they are zooming away at incredible speeds (some near light's velocity) and must be very distant. But if monster black holes are botching up astronomers' spectral yardstick by reddening quasars, then current day theories on the expanding universe might need revision.

What about mini-black holes? Cambridge astrophysicist Stephan Hawking proposes that within the fury of the "big bang" which supposedly created our universe were born billions of baby black holes. Instead of forming from stellar collapse, miniholes would have incubated in microscopic regions forced to contract rather than expand during the explosion. Some theorists have gone so far as to suggest that tiny black holes, each no bigger than a dust speck and roughly the mass of a small planet, may comprise most of the matter in the universe.

Suppose pocket sized holes are even hiding in our solar system, perhaps near Earth. Atomic Energy Commission researchers Lowell Wood, Thomas Wever, and John Nuckolls (noted for their work in laser-induced fusion) suggest that we should find it and put it to work — not as a superefficient garbage disposal but as a powerful new source of energy.

Their scheme sounds like a film sequence out of a "2001" sequel: A spaceship first rendezvous with the newly detected black hole and begins the task of towing it into Earth orbit. Like dangling a carrot on a string before a donkey, the ship tempts the forever hungry hole by tossing it clumps of matter. Mutual gravitation tugs the tiny visitor along as it gulps down each meal until finally it is coaxed into safe orbit. Carrying a payload of hydrogen fuel, another spacecraft cautiously approaches the captured whirlpool. From just outside the boundary where the tiny hole's gravitational field turns deadly (a few hundred feet), the vehicle shoots hydrogen pellets into the black abyss. Increasingly powerful gravity compresses each pellet, heating it to fusion temperatures of hundreds of millions of degrees. For an instant a miniature sun blazes brightly, radiating hot electrified gases. Passing through a magnetic field generated by the spacecraft, the glowing gases induce an electric current in coils mounted outside the ship. Converted to microwaves, the energy beams toward huge collecting antennas on Earth to be reconstituted into everyday household current.

Although their exotic idea goes far out on the



Black holes millions of times as massive as the sun are thought to be lurking at the nucleus of almost every large galaxy. Although such holes have not yet been identified observationally, there are theoretical reasons for believing they exist.

Hale Observatories Photograph

limb of speculation, such an "ultimate power plant" would have a list of popular selling points — no moving parts, no pollution, and a practically inexhaustible fuel supply (anything should work as fuel). How you go about first finding baby black holes (if they exist) remains the greatest problem, and realistic solutions may be a long way off.

Perhaps the most bizzare proposal yet coming from theorists suggests that black holes might be funneling matter and energy to far-flung parts of our universe or into neighboring universes. On the receiving end would lie a "white hole", a blazing cornucopia of new matter continuously gushing into another region of space and time.

A quasar's resemblance to a white hole's description makes this theory especially intriguing. If quasars are as distant as astronomers think, then these starlike objects probably glow too brilliantly to be powered by any energy processes we know of. Not much larger in diameter than the solar system, quasars blaze with the intensity of an entire galaxy.

If quasars are the opposite ends of black holes, then the haunting question of where matter goes once vanishing down the cosmic drain is neatly solved. National Radio Astronomy Observatory astrophysicist Robert Hjellming even imagines that quasars might establish a two-way flow of matter between our universe and an alien one, balancing out whatever star stuff we lose with abandoned material coming in from another cosmos.

Could man ever embark on the "ultimate trip" through a black hole's heart and into another realm of space and time? Some theories say it's possible — but only under certain conditions.

First we need a monster black hole measuring hundreds of millions of miles across. Black holes born from individual star collapses, averaging tens of miles in diameter, force incoming objects to go through too frighteningly fast an increase in gravity. But because of their tremendous size, super-black holes should be far more gentle. Entering the gravity field of a large hole in contrast to approaching a normal size hole would be like strolling down a gentle slope compared with stepping into the Grand Canyon.

A normal black hole's surging increase in gravity is so fantastically amplified that even the tiny distance between one's head and feet makes a significant difference. Falling feet first, an unwary explorer might stretch like soft taffy as gravity tugged at his feet more strongly than his head.

Next, the black hole must be rotating. This requirement doesn't seem too demanding since rotation is the rule rather than the exception in the universe. Almost every object in space, regardless of size, spins at some rate.

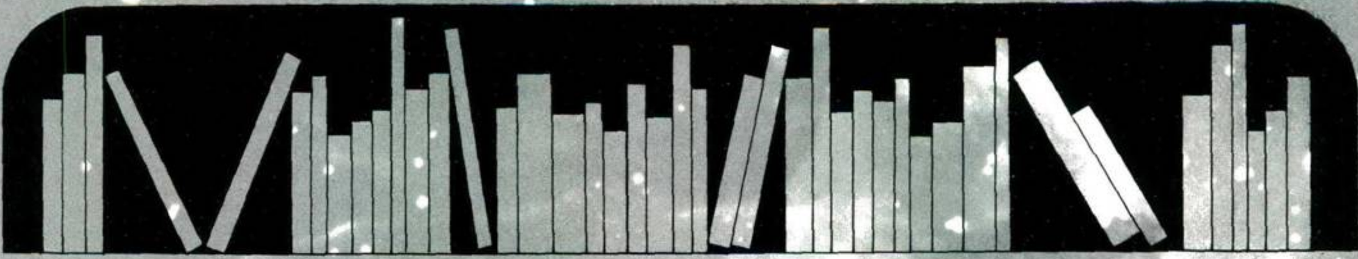
Stars that black holes were born from undoubtedly rotated. During a massive star's abrupt collapse, spin rate has to sharply increase in order to conserve angular momentum — just as a figure skater automatically twirls faster as she shrinks her size by bringing her arms in closer to her body. Additional evidence comes from observations of neutron stars — black holes' relatively lightweight cousins — showing that some whiz around their axis in less than one second!

Recent theoretical work suggests that weird changes occurring in a spinning black hole might open a doorway to other universes. Simply, a rotating hole should develop two event horizons. An astronaut who navigates his ship to fall into the hole at just the right angle to these event horizons would be saved from the jaws of singularity by instead being flung to another region of time and space.

But scientists will probably never know if this exciting theory is true. Even if future explorers someday boldly descend into the black abyss, once past the outer event horizon any communication beams destined for Earth would be forever trapped by gravity. Unless the crew someday found a black hole tunnel leading back to our own time, their fate would remain unknown to all future generations.

Definitely finding a black hole and unraveling its many mysteries ranks among the greatest challenges facing modern astronomy. But the potential rewards far outweigh the effort. Outside of providing a vital new key to understanding the universe's destiny, black holes might prove passageways to dimensions as yet undreamed of.

Daniel J. Willens is a physics major at Wisconsin's Ripon College and former editor of **Fornax**, *a journal published by the Chicago Astronomical Society Student Group. In 1973 he was co-experimenter on one of the student projects flown aboard Skylab.*



ASTRONOMY REVIEWS

The Amateur Astronomer's Handbook
by JAMES MUIRDEN

404 pages, hardcover, $8.95
Thomas Y. Crowell Co. (1974)

A well-known British amateur astronomer and optician has considerably revised and expanded the 1968 edition of his useful handbook, thus making available again a work that has become scarce in this country during the last year or two. Muirden's style is breezy but concise, unlike some of his British colleagues whose "guidebooks" are tough for beginners.

The volume is divided into four parts — I, Equipment; II, The Solar System; III, The Stars and Nebulae, and IV, Optical Work for Amateurs. There are also many useful appendices. The first three sections cover every aspect of visual observing of interest to the astronomy enthusiast, from lunar and planetary studies to searching for comets and making magnitude estimates of variable stars. There is also a chapter devoted to astrophotography (mainly reflecting its state in England, however), and an excellent summary of the showpieces to be found in each constellation.

The fourth part is new to this edition and is perhaps the best "no-nonsense" guide to mirror and lens making in print today. Its concise and easy-to-follow directions take much of the myth and mystery out of the act of making a telescope.

The Amateur Astronomer's Handbook seems very much like a modern version of Charles Edwards Barns' **1001 Celestial Wonders** of the early 1900s, now a rare collector's item. Like his predecessor, Muirden has managed to bring together in one volume "everything you ever wanted to know about... observing".

The Evolution of Radio Astronomy
by J. S. HEY

214 pages, hardcover, $10.00
Neale Watson Academic Publications (1973)

This book presents a very complete account of the development of radio astronomy, giving a detailed outline of the whos, wheres and whens. Because of the emphasis on the history of this exciting field, some sacrifice has been made in communicating the excitement while little sacrifice has been made to historical detail. But for those who are genuinely interested in a complete account of the progress of this science this book is so far unrivaled. Those of us who would like to know more about where radio astronomy is today should turn elsewhere.

Since the emphasis here is on the earlier days of this science, most of the book deals with what was done in Europe. Hey was in on the development of radio astronomy from the early 1940s, and therefore does have a very comprehensive awareness of what happened where and when. However, the book contains few indications that this science, as with so many others, also is plagued by human intrigue and competition. A little more of that aspect would perhaps have made for a meatier and more easily readable book for the interested layman.

Some interesting new photographs of historical importance are spread through the text even if one of them is acknowledged as being a reconstruction of a historical scene! An important part of this book is a very comprehensive list of references of important papers in this field, although the list is probably meant for serious students rather than the lay reader who would not likely find easy access to these papers.

Guideposts to the Stars
by LESLIE C. PELTIER

176 pages, hardcover, $6.95
The Macmillan Co. (1972)

Leslie Peltier is very probably the greatest living astronomical observer in the world today. This Delphos, Ohio amateur has already left more than a half century legacy to science which includes the discovery of a dozen comets, six novae and well over 120,000 variable star observations.

Guideposts to the Stars is an ideal sequel to his first book (an autobiography, **Starlight Nights**, Harper and Row, 1965), for surely few know the skies as well as he does. Every beginning observer should have both of these works. Written with the same wit, charm and excitement as his autobiography, **Guideposts**' basis is the use of the 15 first magnitude stars visible from northern latitudes as guides to all the prominent constellations and star groups. The technique is excellent and Peltier's charts are the clearest and most effective for the purpose to be found anywhere. A series of exquisite sky-horizon sketches done by the author complement the charts and add much to the usefulness of the book.

This work is more than just a constellation guide, however, for many types of celestial objects of interest to the visual observer are treated — including the planets, comets and variable stars. There is even a section on binoculars and small telescopes. All in all, this is one of the best introductions to the sky in print.

Search the Solar System
by JAMES STRONG

160 pages, hardcover, $8.50
Crane, Russak and Company (1973)

This book addresses itself to the unmanned exploration of the planets, an exciting topic of both the present and future. It doesn't take long for a reader to discover that the book is outdated, boring, and so laced with errors as to be worse than useless.

Books have a hard time keeping up with space events these days, so its no shame to be two years out of date as soon as you get into print. What is objectionable is the author's old-fashioned fantasies which are a decade or more behind the times. Outside of detailed descriptions of probes "spiraling into the sun" or "landing on Saturn's rings", Strong repeats the old "hitch a ride on an asteroid" fallacy that had its prime in pre-Sputnik days.

To Strong, the eccentric asteroids are more accessible because they pass closer to Earth. This misconception completely ignores the greater velocity changes a probe needs to land on Eros versus Venus, for example. And Strong envisions a ship catching up with an asteroid, grappling to it, and letting it tow the ship around the solar system. In reality, if the ship had the rocket power to catch up with the asteroid, it would be in the asteroid's orbit and would follow the asteroid's path with or without the asteroid's presence.

The author rarely uses one word where three will do. Wading through the turgid prose, a reader cannot escape the thought that the text was "stretched" to make several distinct short articles into a skimpy book.

The book, worst of all, is so full of other errors, omissions, and distortions that it is downright dangerous. One such absurdity:

"When a space probe finally arrives tangentially to Jupiter's orbit, its initial speed will have been reduced to nearly half, whereas Jupiter will be coming up fast on the outside at a steady eight miles per second. The probe must therefore increase its speed considerably if it is to match Jupiter's velocity and later go into orbit."

The probe, of course, is sped up by Jupiter's gravity and would normally fly past the planet with a speed greater than escape velocity. This speed must be *decreased* by firing the rocket engine to put the probe into orbit around the planet.

Strong talks about robot planetary explorers controlled "instantaneously" by men on Earth; self-controlled autonomous vehicles are not discussed. Strong sees spacecraft power as a long extension cord from Earth; at least, his systems are designed without considerations of power requirements.

This book is not suitable for novices, who would be misinformed; it is not suitable for experts, who would be amused and outraged. Search elsewhere for details on the exploration of the solar system.

The Observer's Handbook 1975

edited by JOHN R. PERCY

110 pages, paperback, $3.00 (Canadian currency)
Royal Astronomical Society of Canada (1974)*

This publication is without doubt the single most useful packet of information that both the casual and advanced astronomy enthusiast can own. It contains more information than any other publication of its type available in the English language. To make a complete list of its contents would require more space than we have available for this review.

Some of the important tabulations include month by month and day by day information on all changing celestial phenomena — including planetary distances and observability, right ascension and declination of the planets and sun, and maps of planetary positions. Times of sunrise, sunset, moonrise and moonset for any day of the year for any place in the United States or Canada is an invaluable aid as are statistics on the orbital and physical elements of the planets and their satellites, lunar and planetary occultations, grazing occultations, positions of the asteroids, and Saturn's satellite positions. The tabulation of the 286 brighter stars includes more information than you'll ever need about each one of them. Lists of the nearest stars, dozens of variable stars, double stars, Messier's catalog, star clusters, nebulae and galaxies are all tabulated in an exhaustive manner that has made this book the standard for all other almanac type publications for the astronomy enthusiast.

One of the most important tables in the book — which provides information that we often get asked for — is the table giving the times of the phenomena of the major moons of Jupiter. Anything that happens to one of the four big moons of Jupiter is tabulated — whether it passes into the shadow of Jupiter, behind the disk of the big planet, or if it's in front of the planet and its shadow is cast on the planet. Times to the nearest minute are given for all of these phenomena throughout the year. This table alone is worth the price of the book if you are an avid Jupiter observer.

This publication is recommended without reservation. Every astronomy enthusiast will find something of interest in it.

**Published by the Royal Astronomical Society of Canada, 252 College St., Toronto, CANADA M5T 1R7.*

Astronomical Calendar 1975

by GUY OTTEWELL

48 pages, paperback, $4.95
Furman University (1975)*

This is the first edition of a well conceived and highly useful guidebook for northern hemisphere observers. Half of this large format book (each page is 11 x 15 inches) is devoted to a month by month rundown of the changing phenomena of the night sky. The two page spreads for each month include a full sky chart with planet and asteroid positions noted on them. A rather complex appearing map of the planetary positions as viewed from above the solar system is soon comprehensible to anyone who takes a little time to read the instructions earlier in the book.

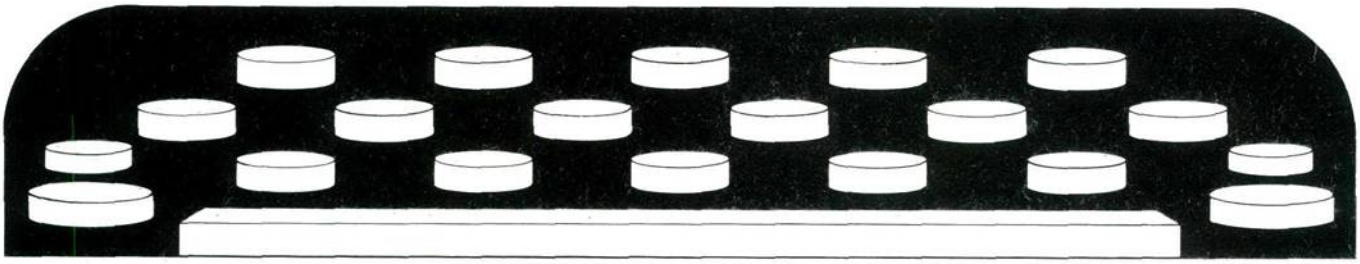
A day by day listing of interesting events such as meteor showers, planetary positions, moon phases and conjunctions of stars and planets round out a comprehensive and well conceived monthly index of sky events for the observer. The sky maps are in places somewhat cluttered and hard to use but more experienced observers will find the information on them useful. However, less useful are the maps of the paths of Neptune and Pluto in 1975. These charts do not show stars anywhere near as faint as the planets themselves and therefore are practically useless for locating these distant worlds. The charts of the paths of Saturn, Uranus, Mars and Ceres *are* useful and like the other supplementary charts are neat and easy to read.

An interesting and unique diagram of double stars visible in amateur size telescopes covers a full page in the publication. Something like this should have been done somewhere else and Ottewell is to be congratulated on his ingenuity in devising the chart. The changing positions of Jupiter's satellites are shown on spiraling orbital charts that give the moons' positions for any time of day or night. However, tables of the moons' disappearance in Jupiter's shadow or the satellites' shadows on the disk of Jupiter are not included. (These are found in the **Observer's Handbook.**)

The **Astronomical Calendar** is very strong on meteors, and observers interested in watching these celestial visitors plunge to their death during recognized meteor showers will be impressed with the thorough coverage. Such basic topics as celestial positions, time, ecliptic, zodiac and precession are well explained with generous use of diagrams.

There is little duplication of the useful tables in the **Observer's Handbook.** The serious observer would be wise to obtain both of these publications if he wants to be equipped with the best available celestial almanacs in addition to the information that appears on the pages of this magazine.

**Published by Furman University, Dept. of Physics, Box 60, Greenville, S.C. 29613.*



IN FOCUS

Sir / On Nov. 12, 1974, I observed the simultaneous shadow transits of two of Jupiter's satellites that you mentioned in the November issue. At 8:30 p.m. PST when I began observations, the shadow of Ganymede was just west of the Great Red Spot. As the evening progressed, it was interesting to watch as the Red Spot "chased" the shadow across Jupiter's disk and gradually overtook it. When I quit at about 10:30 p.m., the shadow appeared right on the Red Spot.

At about 10:15 p.m. I was able to compare the shadows of Ganymede and Europa as you suggested doing in Sky Almanac. Ganymede's shadow was quite obviously larger and easier to see. This was further brought out by the poor seeing conditions that evening. At times Europa's shadow could not be discerned but Ganymede's could still be seen. These observations were made with an eight inch reflector at 140 power.

I also find eclipses of Jupiter's satellites very interesting to watch. Perhaps you could give some consideration to including predictions of these events in your magazine next year.

ROBERT DURISCOE
Van Nuys, Calif.

Mr. Duriscoe / Thanks for your observations. Your request for satellite eclipse times (when the satellites enter or emerge from Jupiter's shadow) has been echoed by other observers. We have considered including this information but have decided not to. If we include that, then there is an endless chain of tables we should include as well. If you are really interested, we suggest you obtain a copy of **The Observer's Handbook** *(see page 17 for a review).*

Sir / In your article "The Zeta Reticuli Incident" (December 1974), you had a photograph pointing out the location of Zeta Reticuli. Curiously I looked on my southern hemisphere star maps to see where it is on the map and I found the star you pointed out is really Mu Horologii. If I'm wrong, can you tell me where and how I can get a new southern hemisphere map?

DAVID RIECYK
Bellmawr, N.J.

Mr. Riecyk / Yes (blush!) we got our arrows crossed. Zeta Reticuli is the bright star directly below the one our arrow points to on page 16 of the December issue. Our star charts are as good as yours but somewhere in the magazine production stage the arrow overlay got shifted.

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Sir / Terence Dickinson left me confused on one point in his article, "The Zeta Reticuli Incident" (December 1974). In defining rotational lock, he uses our moon as an example stating, "Long ago our satellite stopped rotating and now has one side permanently turned toward Earth." I have always understood that the reason for the moon's "standing still" was the fact that it made only one rotation during each revolution of Earth. If indeed the moon did not rotate as Mr. Dickinson says, we would then be able to see all sides of the moon.

PAULA C. GOLD
Cincinnati, Ohio

Ms. Gold / Defining whether or not the moon rotates depends upon your frame of reference. For the moon's motion we actually have a choice of three different frames of reference — the stellar background, the sun and Earth. Relative to the sun, our satellite spins once in every 29 days 12 hours 44 minutes 3 seconds. Relative to the stars, the moon appears to take a slightly shorter time of 27 days 7 hours 43 minutes 12 seconds, because the stellar background slowly shifts as Earth carries the moon along in a yearly orbit. But from Earth's perspective the moon never budges on its axis, always keeping the same face toward us.

The Zeta Reticuli article described how a close solar orbit would gravitationally freeze a planet into keeping one side always facing its sun. As an example we mentioned the Earth/moon system, pretending for a moment that Earth represented a sun and that the moon symbolized a nearby planet. From this perspective our analogy was correct.

Sir / I wish to express my pleasure about your presentation of Marjorie Fish's research on my star map. It was presented in a way in which it could be easily understood by those who have no knowledge of astronomy. Although I was aware of Marjorie's work, it has only been very recently that I began to understand it. When I drew that map, I had no knowledge of astronomy. However, I have always had a good retentive memory. The illustrations were beautiful; I appreciate your fine presentation.

BETTY HILL
Portsmouth, N.H.

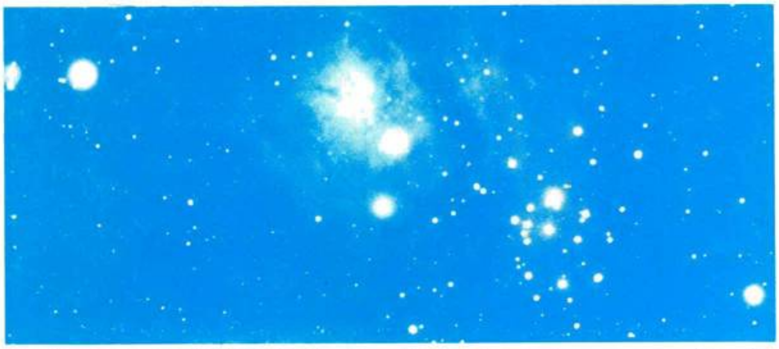
Sir / We note with interest the letter from Robert Purdy in the December issue concerning the unusual satellite-like object which stopped and reversed its direction of travel on July 17, 1974. We have observed similar objects on more than a dozen nights since the beginning of July.

Most of these appeared fourth and fifth magnitudes in brightness, but several as faint as ninth magnitude have been seen in a variety of telescopes including a 10 inch reflector. In each instance, the source moved with the characteristic angular rate and apparent jerkiness (autokinetic illusion) of an artificial satellite. However, the object would suddenly come to a stop, and then either directly double back on its path or move in reverse at an angle of 45 degrees to its original course and disappear.

Several of these sightings involved two objects at the same time, approaching each other from different directions in the sky (one going directly north and the other directly south, for example). Upon closing to within a degree or less, they instantly changed direction of motion just as if they had collided and ricocheted!

All of us have been active observers since the early 1950s, and grew up with Moonwatch and the satellite era. We feel quite familiar with the night sky but have never seen anything like this before this past summer. We are also active in investigating UFO sightings in this area and one of us teaches courses in the subject at our local community college. These contacts have brought to light other observations similar to those reported here from equally qualified and puzzled observers.

JAMES MULLANEY
ROBERT SCHMIDT
WADE BARBIN
THOMAS SHIELDS
Pittsburgh, Pa.



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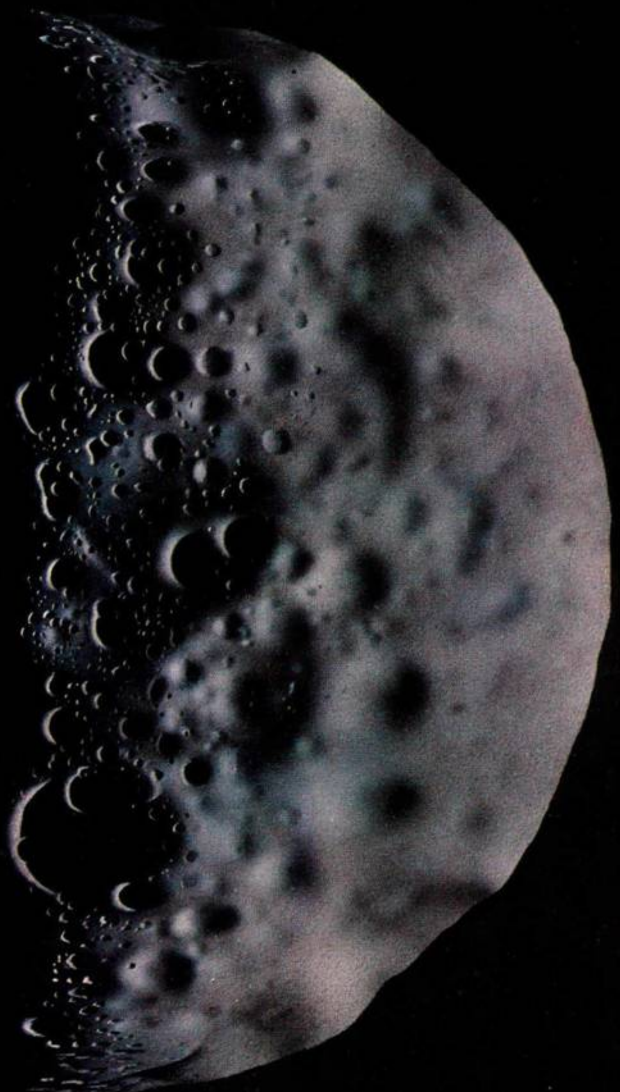
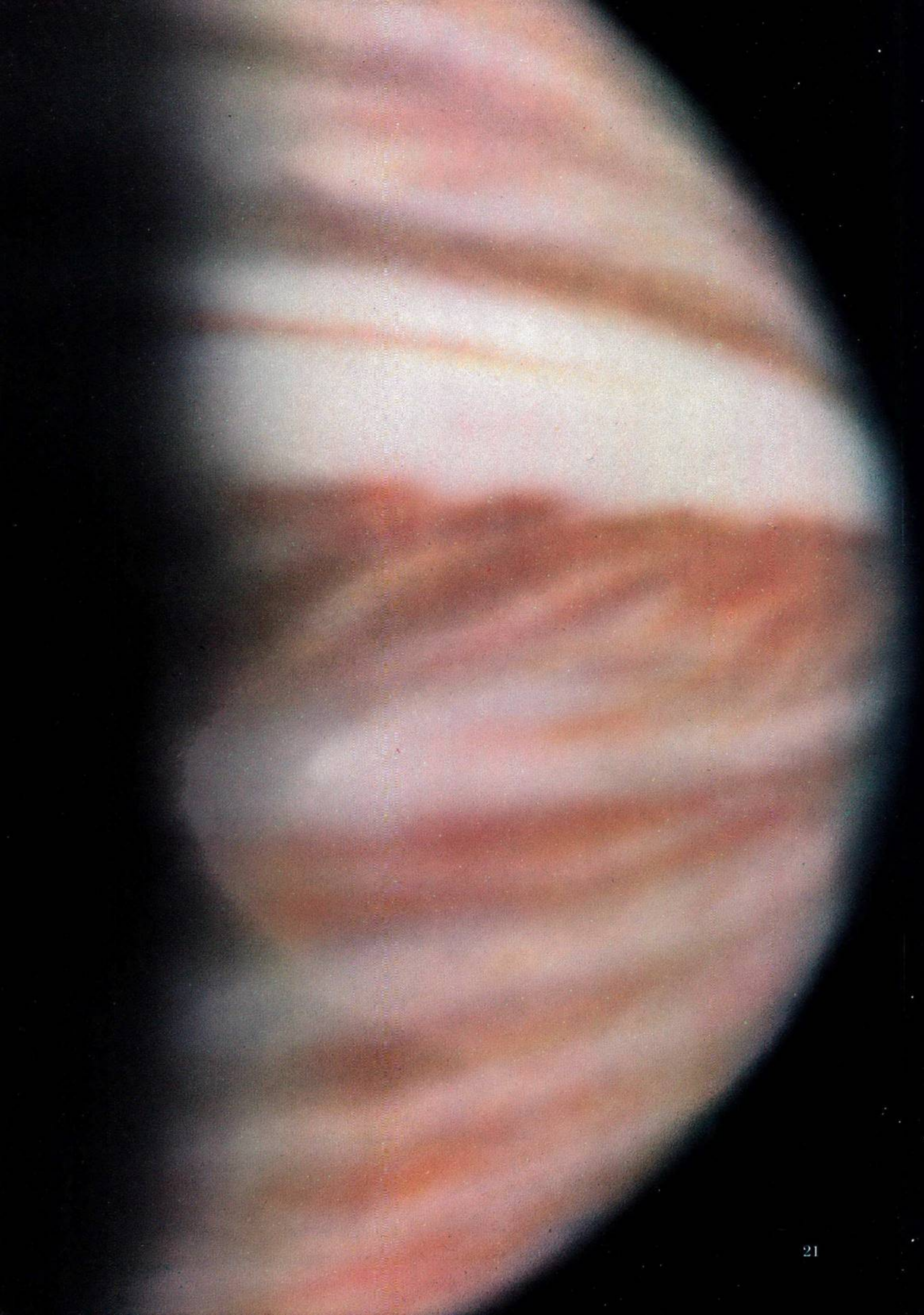
Missions to the Giant Planets

by
Terence Dickinson

The innermost of Jupiter's hoard of 13 moons is Amalthea — a crater pocked, asteroid size world 135 miles across. Circling only 68,000 miles from the giant planet's cloud swept surface, Amalthea is deeply embedded in Jupiter's lethal radiation belts. From Earth this moon is only a speck of light as the photo on page 23 shows, but future robot probes to the outer solar system may reveal details similar to those in this rendering.

Artwork by Adolf Schaller





Four hulking worlds — together comprising about 99 percent of the planetary mass of the solar system — ponderously navigate colossal orbits around the sun at distances ranging from 5 to 30 times Earth's distance from our star. Together these worlds — Jupiter, Saturn, Uranus and Neptune — are known as the giant planets. They are as different from Earth as they could possibly be and yet still have the designation planet.

There seems to be virtually no basis for similarity when Earth and one of the big four is compared in detail. Even the smallest of them, Uranus, has 15 times the mass of Earth. It is surrounded by an atmospheric cloak that is certainly thousands of miles in depth. In fact, Uranus and the other giants are really huge balls of atmosphere rather than spheres of rock and metal like our planet.

There is a generally accepted theory that explains why the giant planets are so different from Earth, Venus, Mercury and Mars — the four inner rock and metal worlds. The theory traces back to the origins of the solar system some 4.6 billion years ago. At that time, the sun and planets were forming from a disk shaped cloud of dust and gas (mostly hydrogen) that was slowly condensing as it rotated. Once enough material had collected at the center of the cloud, the gravitational attraction at that point caused a headlong rush of surrounding matter that increased the cloud's core temperature enormously. This produced the protosun which, for a short period, flared with perhaps 50 times the intensity of the star that we now call the sun.

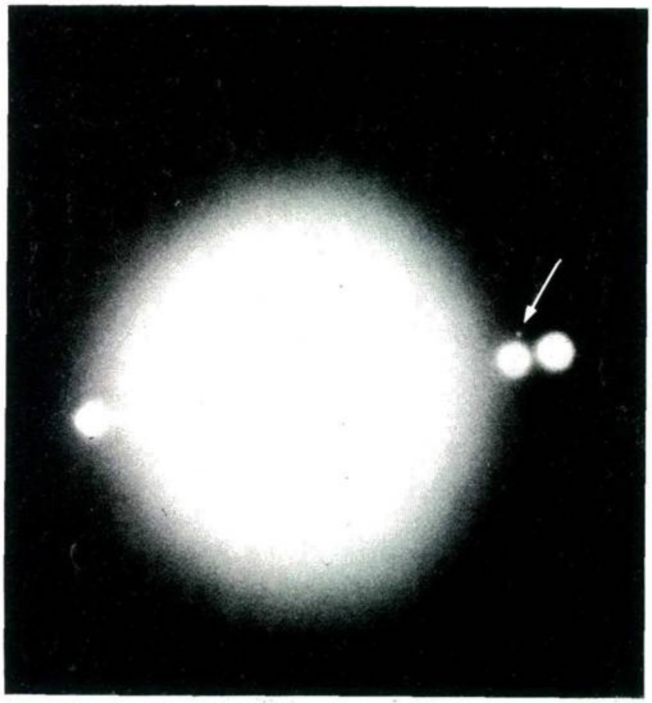
The ferocious but brief fireball blasted off the cloak of light gases that surrounded what would later become Mercury, Venus, Earth and Mars. This energetic celestial hurricane in effect stripped the inner planets naked leaving only their rock and metallic cores; that's what we're living on today. There may be something similar to Earth at the center of each of the four giant planets but it may be sometime before we can be sure.

Jupiter, Saturn, Uranus and Neptune — escaping the fury of the protosun's energetics because of their distance from the center of the solar system — were thus able to retain a significant fraction of their blankets of primordial hydrogen and helium. Indeed, the measurements made by Pioneer 10 as it whipped by Jupiter in late 1973 confirm that the biggest planet is probably 98 percent hydrogen and helium. The percentage may be as high for the other three giant planets.

There is a growing conviction among planetary scientists that the giant outer planets and their satellite families may hold the secrets of the origin

of the solar system — secrets that were ravaged by the events that took place in the inner solar system where we evolved. The belief is that the four giants have changed little since the dawn of the solar system — their huge bulks retaining from that time to this the matter that we see today. One especially significant fact that was rather shortsightedly overlooked until very recently by almost all astronomers was that the satellites of the giant planets probably hold some of the same secrets that the big planets have and that they too may be essentially unchanged from their origins — a situation that decidedly was not the case with the moon despite early hopes. The Apollo missions have shown that a great deal of violence was associated with the first half billion years of the moon's history. We don't know if any of the 32 known moons of the giant planets will enable us to trace things closer to our solar system's origins but it is possible. And since these worlds are small, it will be relatively easy for robot landers to explore them as opposed to the virtually bottomless atmospheres of the planets themselves.

So there are compelling reasons to seriously reach out and find out more about the long neglected giants of our sun's attendant worlds. Already a significant increase in our knowledge of Jupiter has resulted from Pioneer 10's historic first visit to the big striped world in December 1973, and Pioneer 11's repeat of that performance (although in a different trajectory) a year later. What the Pioneers have told us is that Jupiter's environment, though deadly dangerous for a manned spacecraft, can be negotiated by a moderately protected robot vehicle. The way is now clear for the planning and execution of further exploratory missions to Jupiter and the big worlds beyond.



McDonald Observatory Photograph

Jupiter's small inner moon Amalthea is difficult to see or photograph from Earth. Here the late G. P. Kuiper caught the 13th magnitude satellite just above Europa in a 60 second exposure through the 82 inch telescope in 1955. At that time only a handful of scientists were engaged in planetary research and probably none of them would have considered it remotely possible for us to have close-up photos of these worlds in the foreseeable future.

Since the late 1960s serious planning has been underway to do just that. At first the focus was on a remarkable alignment of the giant planets that allowed a single spacecraft to get a gravitational boost from each one as it caromed like a billiard ball from Jupiter to Saturn to Uranus to Neptune. This imaginative project called Grand Tour was later revised to have two spacecraft that together would visit not only the giant planets, but also swing by Pluto. One of the craft was to visit Jupiter, Saturn and Pluto while the other one scanned Jupiter, Uranus and Neptune.

Uranus and its family of moons are virtually uncharted territory. No cloud markings have ever been definitely recorded on the planet by Earth based observers, and the five moons are faint specks even in the largest telescopes. At a distance of 1.7 billion miles, Uranus will require five years to reach even if a spacecraft gets a gravity assist from Jupiter on the way. In the foreground the landscape of Umbriel may be composed of the original material — now frozen — that comprised the primordial solar nebula from which the planets evolved. Another satellite, Ariel, floats some 50,000 miles away in this rendering of the seventh planet.

Artwork by Rick Sternbach

The Grand Tour was like nothing ever envisioned before for an unmanned spacecraft. For such a mission to get from Earth to Neptune or Pluto, a decade of reliable spacecraft performance would be essential. To build a spacecraft that could virtually repair itself and remain operational for 10 years would be an enormous undertaking. Estimates of its cost came in at a staggering $800 million — about the same as the incredibly complex life detection Viking mission that will journey to Mars in 1976. The rationale for a highly complex and costly mission to search for life on Mars was deemed justifiable by Congress and will be launched later this year.

But the Grand Tour did not fare so well. It was rejected from serious consideration in 1971. That decision sent planetary exploration enthusiasts away, licking their wounds and mumbling about loosing a once-every-176-year chance to use the gravity assist to explore all the planets in the outer solar system.

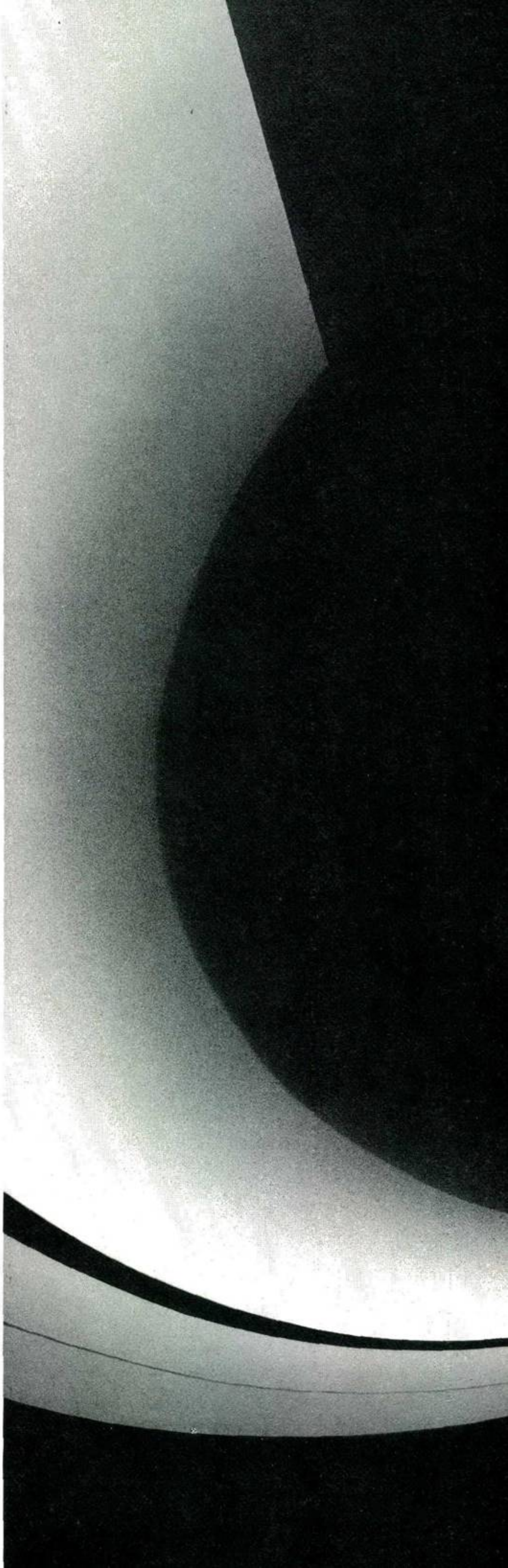
However, a compromise mission that has been under study for three years is now funded. It's turning out to be hardly a compromise but is instead a spectacular opportunity to explore Jupiter and Saturn and at least five of their moons. Scheduled for launching in late summer 1977, the two spacecraft (to be designated Mariners 11 and 12 once they are en route) will be almost identical to the highly successful Mariner 10 — the first double planet exploratory mission. Mariner 10, as you will recall, swung by Venus in February 1973 and hurtled on to a close pass behind Mercury — a flight that included some navigation juggling resulting in a second flyby past Mercury six months later. The Mercury photographs from Mariner 10 revealed surface features 5,000 times smaller than could be distinguished with Earth based telescopes. Even more startling increases in resolution can be expected from Mariners 11 and 12 as they soar by Jupiter's and Saturn's satellite families and take thousands of images of the cloud swept faces of the planets themselves.

What more can we learn from Mariners 11 and 12 that we couldn't find out from Pioneers 10 and 11? Pioneer 11 *is* on its way to a 1979 Saturn encounter and *both* of these spacecraft passed closer to Jupiter than the followup Mariners are scheduled to. So what can we expect to gain especially for a price tag of $309 million as opposed to $100 million for the two Pioneers? It's difficult to predict the results from a space mission — especially when it's heading toward worlds that have never been explored before. The primary advantage here will be the use of Mariner class spacecraft which are three times larger and far more sophisticated than the Pioneer vehicles. Ralph F. Miles — mission analysis and engineering manager for the project (known at this point as the Mariner Jupiter/Saturn 1977 project) — says, "We expect to make substantial information gains at Jupiter and its satellites and to break totally new ground as far as Saturn and its moons are concerned."

Miles, who has been on the project since its inception in 1972, tells us that hundreds of mission trajectories are possible for Mariners 11 and 12 depending on how close we want to get to each planet and which of their extensive families of satellites we wish to explore. The trajectory is constrained somewhat at Jupiter because the gravity of that planet has to be used with great precision to ensure that the craft will be flung at high velocity in a precise path toward Saturn.

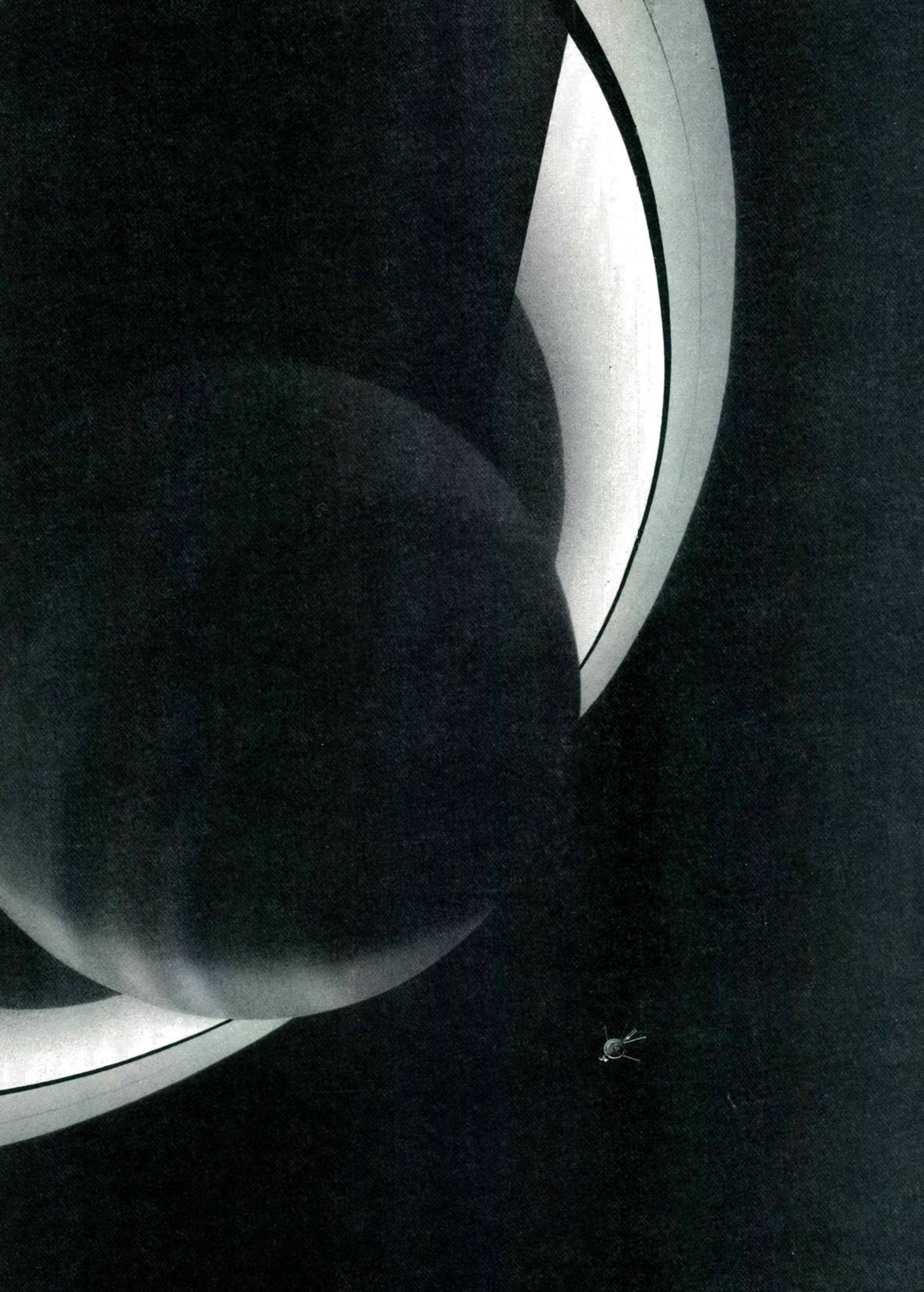
Let's take a look at the plan that has been developed at the Mariner Jupiter/Saturn project office at the Jet Propulsion Laboratory. (JPL is run for NASA by the California Institute of Technology.)

The two spacecraft will be launched within weeks of each other in late August or early September 1977. Mariner 12, the second robot to be launched, will be the first one to arrive at Jupiter because of the geometry of its trajectory. The preliminary scheduled arrival date is March 7, 1979 at 1:11 a.m. EST. (Although it seems incredible to be talking about accuracy in minutes on a mission that has yet to be launched, hundreds of such practice trajectories have been run through JPL's computers — and this one satisfies the majority of scientists associated with the project.) At closest approach the craft will swing



Mariner 11's cameras and sensors furiously record precious information as it swings to within 75,000 miles of Saturn's south polar region. This encounter, planned for early 1981, could be our last close-up look at Saturn until the 1990s when Jupiter's gravity can again be used for a double planet mission.

Artwork by Adolf Schaller



just inside the orbit of Io, the innermost of Jupiter's four big moons, at a distance of 170,000 miles from the Jovian cloud tops — about twice as far as Pioneer 10 was and more than six times farther than Pioneer 11 dared to go on its successful swing by the big planet.

About three hours after closest approach to Jupiter, the craft will come to within 20,000 miles of Io. Because the spacecraft and the satellites are both moving in the same direction around Jupiter, there will be an extensive period of close-up photography of that moon. Miles estimates that at least 200 photographs can be taken showing features smaller than a mile across and a few of the photos will show football field sized objects on Io. The coverage should be comparable to Mariner 10's second pass by Mercury.

(The pronunciation of Io is open to some debate. Astronomers and space science engineers can be heard using both E-oh and Eye-oh. Historical research by JPL's Ray Newburn has revealed a preference for Eye-oh.)

A prime objective of the close approach to Io, besides the photography, is the passage through the so-called "flux tube" — a zone where a decrease in charged particle flux is expected because particles spiraling along magnetic lines of force that loop from one Jovian magnetic pole to another are absorbed by Io as it progresses in its orbit. The flux tube is therefore a "vertical", cylindrical, phantomlike zone that accompanies the moon. Scientists interested in the biggest planet's magnetic field are particularly excited about this part of Mariner 12's odyssey. (Curiously Pioneer 11 did not detect evidence of the flux tube as reported in Astro-News. Mariner 12's more sensitive instruments should settle this question.)

Naturally hundreds of photographs of Jupiter will be included in the flyby, but these will — momentarily at least — be secondary to the sensational aspect of the Io photographs. The Jupiter photos will show details down to about two miles resolution, and the interacting of the streaming clouds will be seen in far greater detail than was available from the Pioneer photos. The coverage of Jupiter will begin three months before each spacecraft makes its closest encounter at a time when the Jupiter resolution will be comparable to the finest Earth based photos. The eight inch telescopes on both Mariners will exceed even the best Pioneer resolution as far out as five million miles from the big planet. From then on we will be seeing more detail than ever before. We should obtain an atlas of several thousand photos of Jupiter as a result of these two missions. After Mariner 12 encounters Jupiter it will be photographing the crescent planet on the way out as it recedes at 70,000 m.p.h.

Exactly a month after Mariner 12's arrival at Jupiter, Mariner 11 will swing by the giant globe about 50,000 miles farther out. Its coverage of Jupiter will overlap that of its predecessor resulting in an extended period of high resolution mapping of the rapidly spinning planet's changing cloud structure. This should give significant insight into the short term variations in Jupiter's wind belts as well as the details of changes that have been observed from Earth over a period of weeks and months. Neither spacecraft will take color photos although some "fake" color may be arranged by superimposing filtered images.

A prime objective of Mariner 11 at Jupiter will be close encounters with two satellites — Ganymede and Callisto. On the way in through the satellite family, Ganymede will be photographed and scanned with other sensors from a distance of approximately 25,000 miles, while Callisto will be examined from about 70,000 miles away during the spacecraft's exit from the satellite system. Low resolution photos of the other satellites including Amalthea and Europa may be attempted by both spacecraft. However, the eight midget outer moons of Jupiter, ranging in distance from 7 to 15 million miles from the planet, will not be the concern of the Mariner robots since none of these satellites will be anything more than a starlike point in the spacecraft's imaging systems. They are simply too far away from Jupiter and the spacecraft trajectory to be resolved. The task of a 1980s Jupiter orbiter may include the study of these outer moons, but we'll get to that later.

About two years after Jupiter encounter, the two vehicles will be in the vicinity of Saturn — Mariner 12 once again to arrive first on Nov. 21, 1980. It will

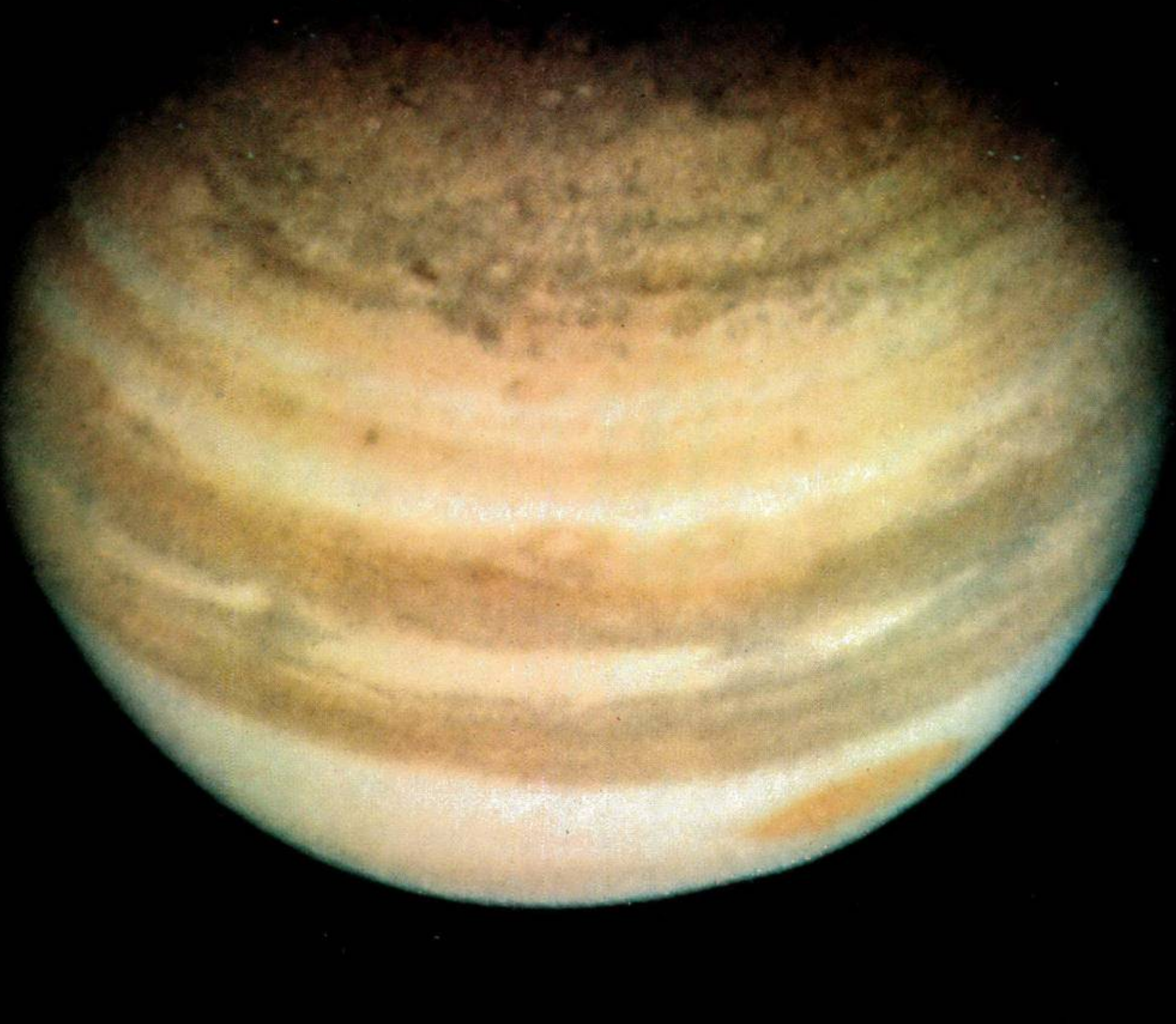
The Giant Planets Compared to Earth

Name	Equatorial Diameter (miles)	Mass (Earth=1)	Rotation Period	Revolution Period (years)	Distance from Sun (millions of miles)
Earth	7,927	1	24^h	1	93
Jupiter	88,730	318	9^h50^m	11.86	484
Saturn	75,100	95	10^h14^m	29.46	886
Uranus	29,200	15	10^h49^m	84.01	1,782
Neptune	31,650	17	16^h $?^m$	164.8	2,792

be targeted to swing behind the planet so that earthbound radio signals will pass through Saturn's atmosphere as well as through the rings and the gap between the rings and the planet. Dramatic new insights into the nature of the rings and their dimensions should result from this occultation sequence and accompanying photography.

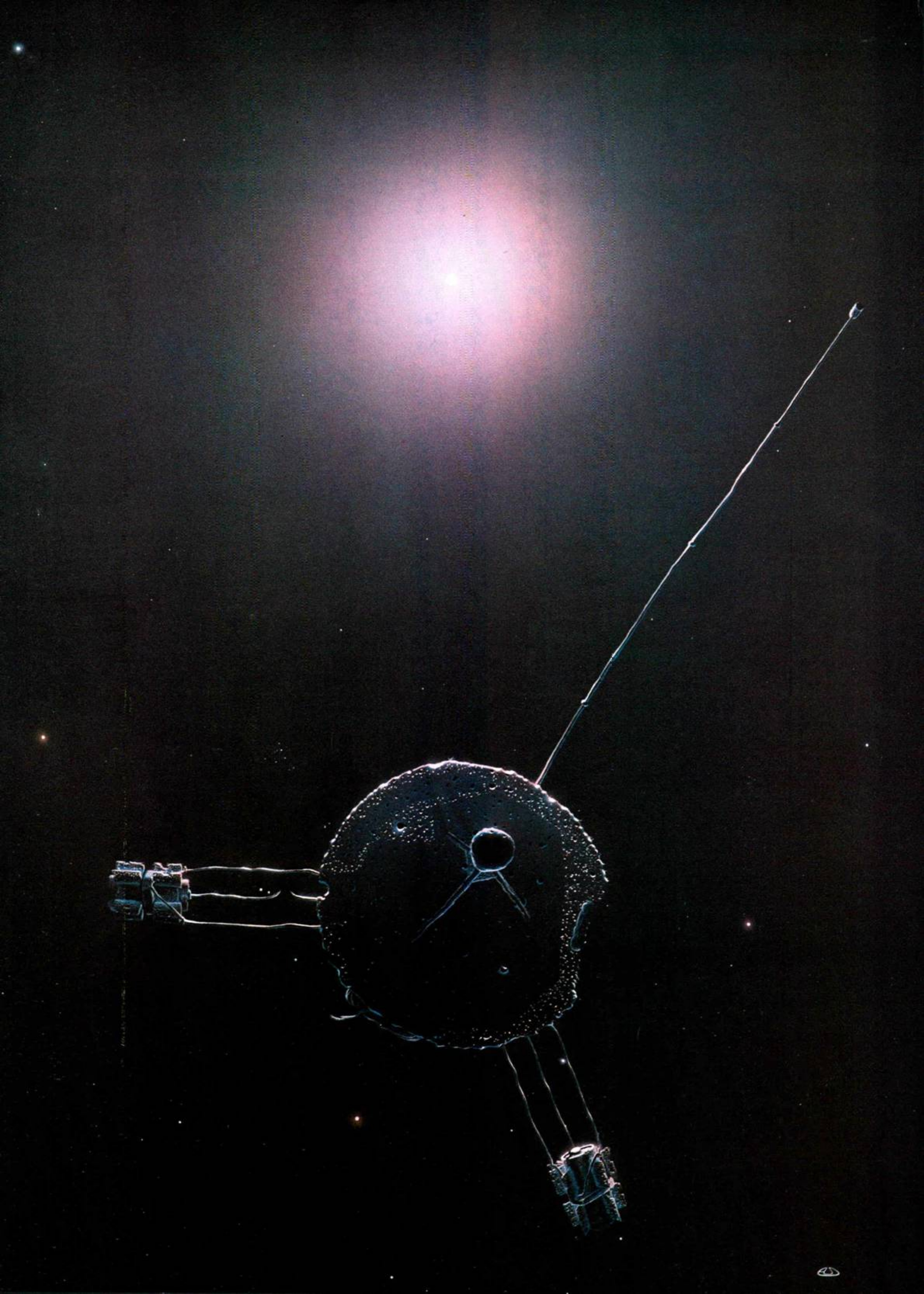
After looping behind Saturn, our interplanetary explorer will have a photographic field day as it passes 50,000 miles below Mimas, 40,000 miles from Tethys and a scant 6,000 miles above Dione. A few dozen photos of each moon will record mile wide surface features on these objects — worlds that appear only as pinpoints in even the largest Earth based telescopes. But before leaving the Saturnian system, Mariner 12 will scan the giant moon Titan from about 100,000 miles away as a prelude to a much closer approach by Mariner 11, soon to close in on the ringed planet.

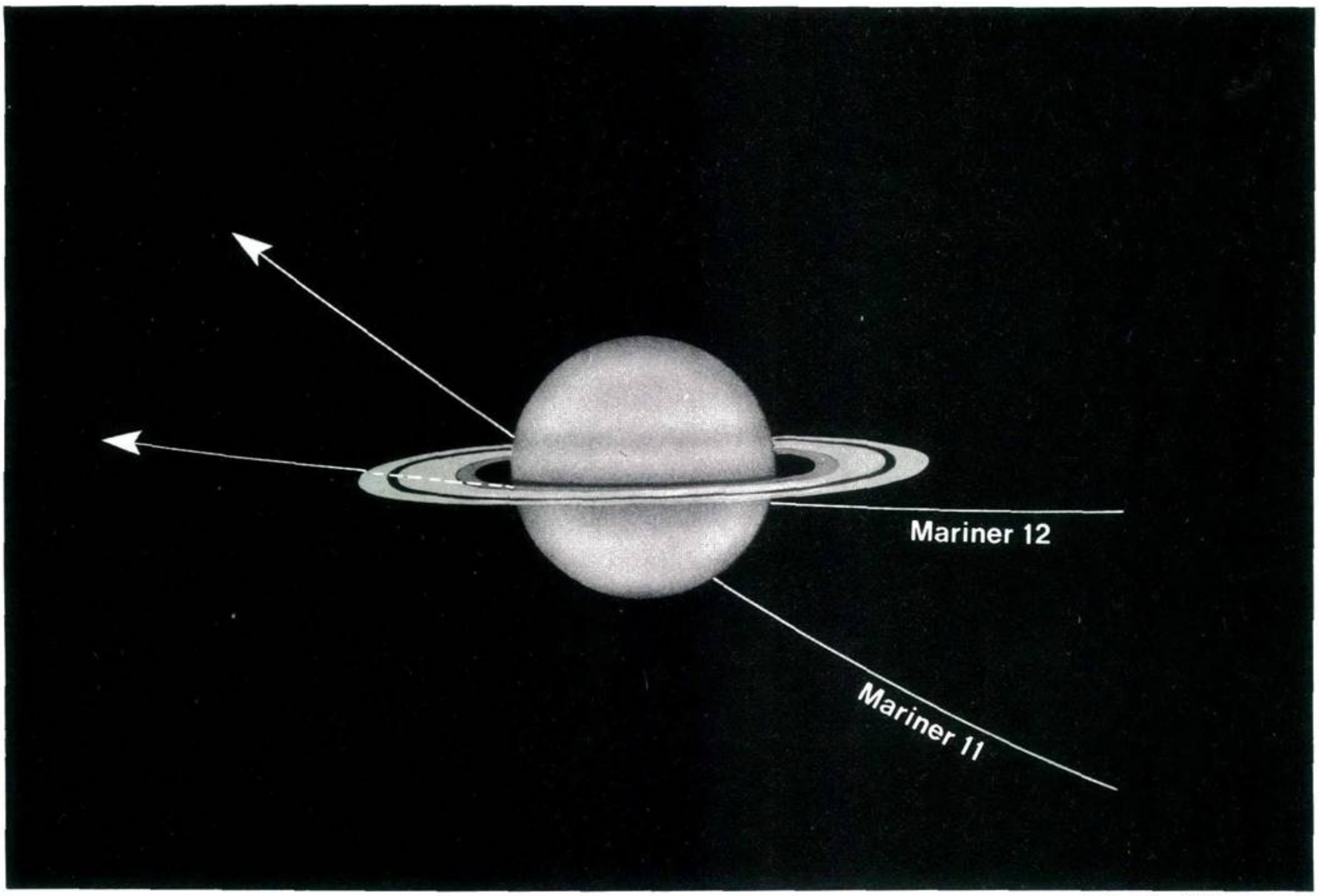
As engineers and scientists digest the wealth of new information from the historic Saturn encounter, Mariner 11 will be prepared for a rendezvous only 17,000 miles from the 3,600 mile wide Titan. The only planetary satellite known to have an extensive atmosphere, Titan is an object of intense scientific interest. (An article devoted entirely to Titan will appear in a future issue.) To learn as much as we can about the solar system s biggest moon, Mariner will fly behind it so that transmissions will be briefly filtered through its atmosphere — a power-



The never-before-seen north polar region of Jupiter was photographed by Pioneer 11 shortly after it hurtled around the planet's night side on Dec. 2, 1974. The pole itself is roughly on the terminator (boundary between Jovian day and night) across the top of the planet. The grayish-blue polar areas seem to have rising "convection cells" like thunderstorms on Earth or bubbles in boiling water. The picture does suggest that the polar regions are somewhat more placid than the vigorously circulating equatorial areas. Scientists have suggested that the polar regions are relatively stagnant providing a favorable environment. All the elements for life including the planet's internal energy appear to be present in the polar regions. This view of Jupiter was taken 750,000 miles from the huge planet. After leaving Jupiter, the Pioneer 11 spacecraft will fly 100 million miles above the plane of the solar system, and then swing down to an encounter with Saturn in 1979.

NASA Photograph





Artwork by Victor Costanzo

In late 1980 or early 1981, Mariners 11 and 12 will hurtle behind Saturn as part of their exploration of the ringed planet and its satellite system. Saturn's gravity will fling both spacecraft on paths that will carry them completely out of the solar system.

ful technique for determining atmospheric density and content. Both inbound and outbound, the cameras will be recording detail in the suspected heavy cloud cover on Titan.

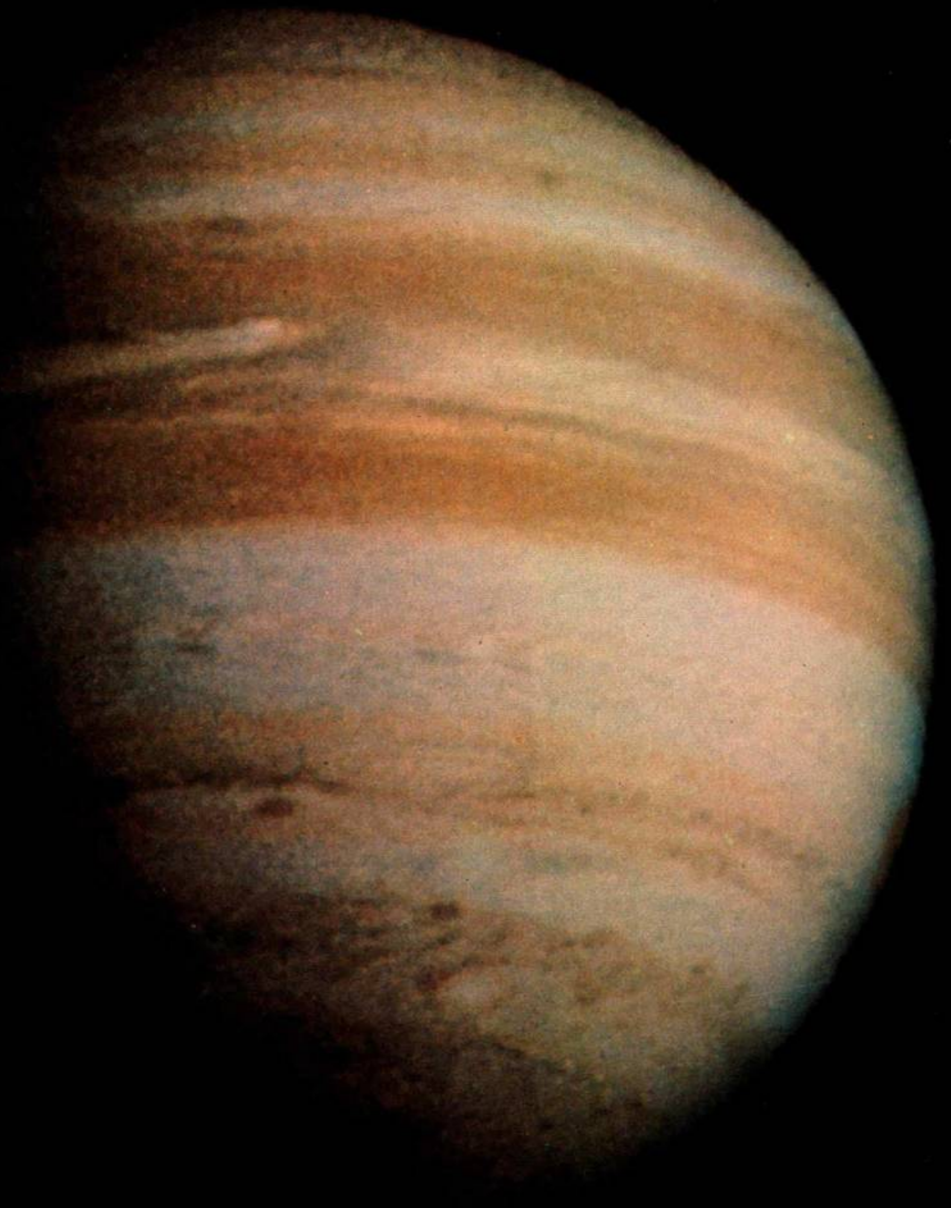
Before reaching Saturn, Mariner 11 will have a look at Rhea from 60,000 miles. A looping pass under Saturn's south pole is planned with a bonus look at Dione from 50,000 miles away. Then, streaking away at an average velocity of 45,000 m.p.h., both robots will be out to Pluto's distance from the sun (35 times Earth's) by 1990. Somewhere out there at the frontier of the solar family, the space probes will cease to function — having exceeded their designed lifetimes. Before that happens they may break through into interstellar space — territory unmodulated by the solar wind. The craft will be purposely targeted to head out of the solar system in the direction of the sun's motion in the galaxy. There has to be someplace where the solar influence meets the interstellar medium. Right now nobody knows where that is.

Keep in mind that the specific dates, distances and trajectories mentioned here only refer to two *possible* flight plans. Changes may be desirable as more data from Pioneer 11 is analyzed. Continuing research by mission planners and scientists could also alter the preliminary plans.

What about using Saturn's gravity to fling one of the Mariners on to the next planet, Uranus? According to Ralph Miles it's not being considered. He says a trajectory to Uranus "would require a passage either right through the rings or very close to them, a chance we are not prepared to take — yet". However, a Uranus mission is on the drawing boards although whether it will fly or not depends on availability of funds.

Like Mariners 11 and 12, the Uranus probe will use Jupiter's gravity to hurl it on to its objective. To be launched in 1979 for Jupiter encounter in 1981, the spacecraft (it may be a Mariner or the less sophisticated Pioneer type vehicle) will bypass Saturn and reach Uranus in 1985. There is a possibility the spacecraft may be equipped with an atmospheric entry probe that will be dropped into Uranus' clouds. The probe would be designed to survive to a depth where pressures exceed 10 times Earth's sea level air pressure. Due to the outer planet alignment mentioned earlier, the Uranus mission will not be able to use Jupiter's gravity "assist" after 1980 — so if this op-

Passing near some uncharted star a million years from now, the meteoroid-battered remains of Pioneer 10 will represent the oldest surviving artifact of man. Long after today's artificial Earth satellites and sun orbiting probes have collided with a planet of our solar system, this spacecraft will be silently plying an unrecorded trek between the stars.
Artwork by Adolf Schaller



The day before Pioneer 11's closest approach to Jupiter it recorded this detailed image of the largest planet. The multicolored clouds that top Jupiter's massive atmosphere are whirled into streaming bands by the planet's 10 hour rotation. The Great Red Spot is just disappearing from view at right. Jupiter's south polar region can be glimpsed but the spacecraft had a much better view of the north pole as the photo on page 27 shows. Results of this mission are detailed in Astro-News.

NASA Photograph

portunity is missed, Uranus exploration will probably be delayed until at least 1992.

Next on the outer planet exploration timetable is a Jupiter orbiter that would arrive at the giant planet in 1981, inserting itself (with the help of a "gravity-brake" effect from Ganymede) into a 650,000 mile by 7,000,000 mile elliptical orbit. From this looping vantage point we could get our first look at one or two of Jupiter's outer moons which revolve around the planet at the space vehicle's maximum distance. The tiny outer moons of Jupiter are all less than 100 miles wide and could be the remnants of a smashed moon, or asteroids captured by the giant planet's mighty gravity.

THE SATELLITES OF THE PLANETS

	Visual Magnitude	Average Distance from Planet's Center (miles)	Revolution Period	Diameter (miles)	Mass (moon=1)	Density (water=1)	Albedo* (percent)
Satellites of Earth							
Moon		238,900	$27^{d}\ 07^{h}\ 43^{m}$	2,160	1.0	3.3	12
Satellites of Mars							
Phobos	11.6	5,800	0 07 39	14	—	—	06
Deimos	12.7	14,600	1 06 18	8	—	—	07
Satellites of Jupiter							
Amalthea (V)	13.0	112,000	0 11 57	135?	—	—	—
Io (I)	5.0	262,000	1 18 28	2,260	1.24	3.50	62
Europa (II)	5.3	417,000	3 13 14	1,925	0.66	3.42	68
Ganymede (III)	4.6	665,000	7 03 43	3,275	2.03	1.95	44
Callisto (IV)	5.6	1,171,000	16 16 32	3,100	1.45	1.65	19
Hestia (VI)	14.7	7,133,000	250 14 —	100?	—	—	—
Hera (VII)	16.0	7,295,000	259 16 —	35?	—	—	—
Demeter (X)	18.8	7,369,000	263 13 —	11?	—	—	—
Adrastea (XII)	18.3	13,200,000	631 02 —	10?	—	—	—
Pan (XI)	18.6	14,000,000	692 12 —	14?	—	—	—
Poseidon (VIII)	18.1	14,600,000	738 22 —	10?	—	—	—
Hades (IX)	18.8	14,700,000	758 — —	12?	—	—	—
Satellites of Saturn							
Janus	14	100,000	0 17 59	135?	—	—	—
Mimas	12.1	116,000	0 22 37	250?	0.0005	1.1	—
Enceladus	11.8	148,000	1 08 53	300?	0.0012	1.3	—
Tethys	10.3	183,000	1 21 18	600?	0.009	1.2	—
Dione	10.4	235,000	2 17 41	700	0.016	1.5	60
Rhea	9.7	327,000	4 12 25	1,000	0.024	1.7	60
Titan	8.4	759,000	15 22 41	3,600	1.91	1.4	15
Hyperion	14.2	920,000	21 06 38	200?	0.004	—	—
Iapetus	10.2-11.9	2,213,000	79 07 56	950	0.013	—	variable
Phoebe	16.5	8,053,000	550 11 —	135?	—	—	—
Satellites of Uranus							
Miranda	16.5	77,000	1 09 56	250?	0.002	—	—
Ariel	14.4	119,000	2 12 29	850?	0.02	—	—
Umbriel	15.3	166,000	4 03 38	600?	0.007	—	—
Titania	14.0	272,000	8 16 56	1,100?	0.07	—	—
Oberon	14.2	365,000	13 11 07	1,000?	0.03	—	—
Satellites of Neptune							
Triton	13.6	220,000	5 21 03	2,500?	4.6?	—	—
Nereid	18.7	3,461,000	359 10 —	400?	—	—	—

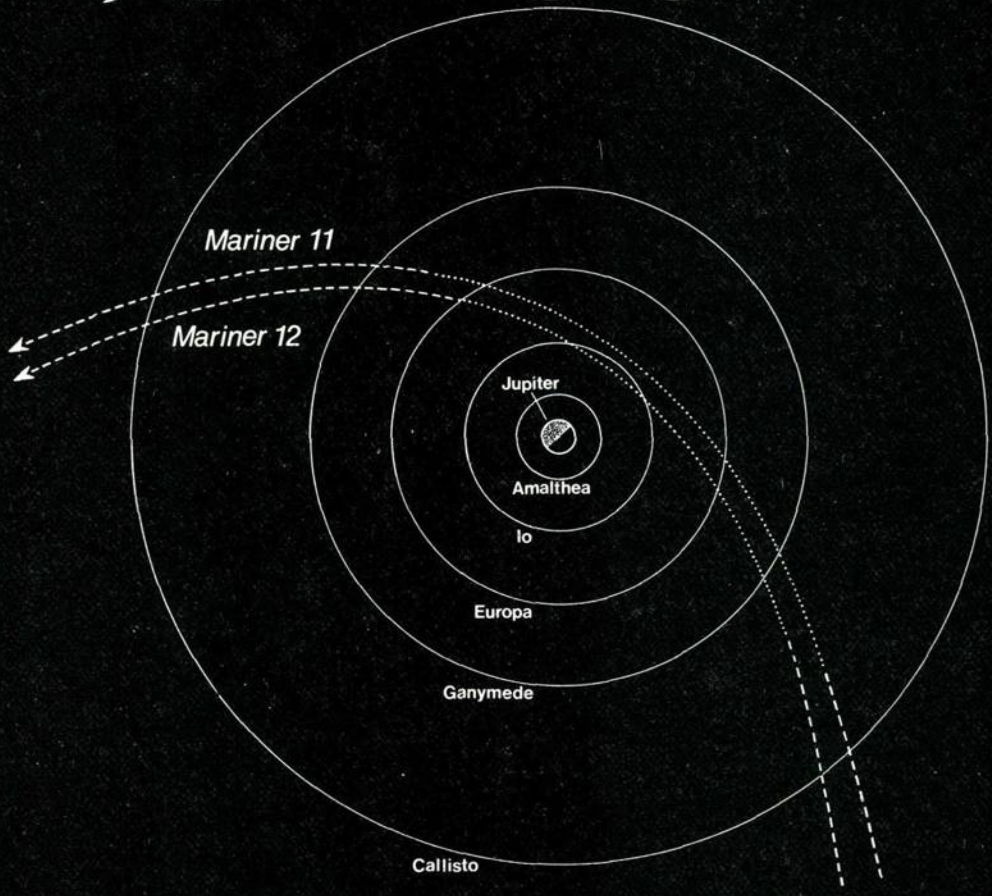
* Albedo is the percentage of sunlight reflected back into space by the satellite's surface and/or atmosphere.

The following satellites orbit their primary in the opposite direction from the normal (counterclockwise) direction: Adrastea, Pan, Poseidon, Hades, Phoebe and Triton.

Throughout the table a dash indicates unknown data.

Statistics for this table were compiled from data presented at the International Astronomical Union Colloquium on Planetary Satellites, Cornell University, August 1974.

Two Jupiter Flybys in 1979



Dotted portion of trajectories are below the plane of the satellite orbits.

"The Jupiter orbiter would be a remarkably flexible mission," says John C. Beckman, Mariner Jupiter Orbiter study chief at JPL's Advanced Projects Mission Analysis division. He says recently discovered methods utilizing gravity assists from the four big Galilean moons would "give a Mariner class orbiter the equivalent power of a Saturn 5 rocket".

It would work this way: The orbiting Mariner would be maneuvered slightly so that on its next orbit it would skim to within a few hundred miles of, say, Callisto. Such close passes would alter the craft's orbit in a predetermined way so that its viewing angles of Jupiter and its moons could be constantly revised. Over a two year period the Jovian weather could be mapped in more detail than could be scientifically digested for years to come. All four major moons would be virtually totally mapped to a resolution equivalent to the visual appearance of our moon in a moderate sized telescope. During some of the trajectory maneuvers, photos of objects as small as a barn could be detected on a Jovian satellite! There is even the capability of placing the vehicle in orbit around one of the moons if something interesting prompts detailed investigation.

What comes after the Jupiter orbiter? Beckman tells us, "It is strictly arm waving — nothing specific is being seriously studied at this time. Neptune and Pluto, although not beyond our capabilities, are not seen as targets for a long time."

The earliest mission after the Jupiter orbiter (assuming there will be a Jupiter orbiter) could be an attempt to land a capsule on Titan in the late 1980s. That same flight could include a Saturn atmospheric probe or a rings suicide mission.

Robot planetary explorers are man's eyes and hands and mind extended to places he cannot yet venture. The secrets of the giant planets are gradually being revealed. Slowly, but inevitably, the entire solar system will be surveyed. We will then, for the first time, understand the contents of our celestial backyard.

For more information about exploration of the giant planets and their satellites, consult the following articles in recent issues of ASTRONOMY: "The Forbidden Moons" and "Pioneer 11 To Visit Saturn", May 1974; "Planetary Bonanza", June 1974; "New Jovian Vistas", November 1974, and "Saturn — The New Frontier", January 1975.

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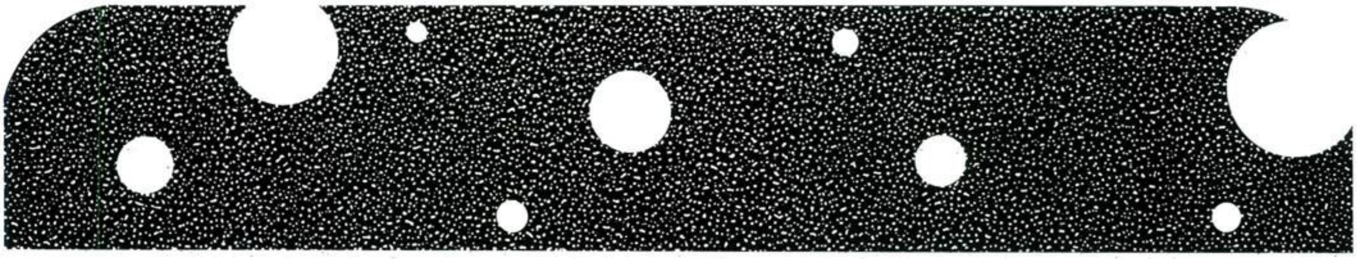


STELLAR FRONTIERS

Ultraviolet Astronomy

by
Gerrit L. Verschuur

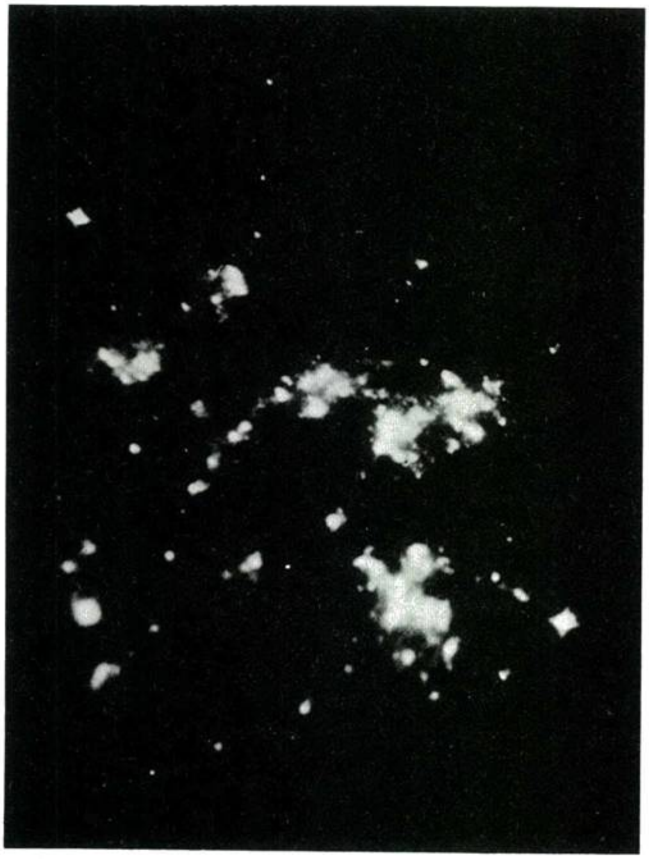
Thanks to blacklight posters and related psychedelia sold over the past few years, ultraviolet (UV) light has become one of the most popularized regions of the electromagnetic spectrum. Blacklight is a fitting nickname for ultraviolet light since its wavelength falls just beyond the shortest wavelength of light our eyes are sensitive to (something like a sound that is too high pitched to hear).

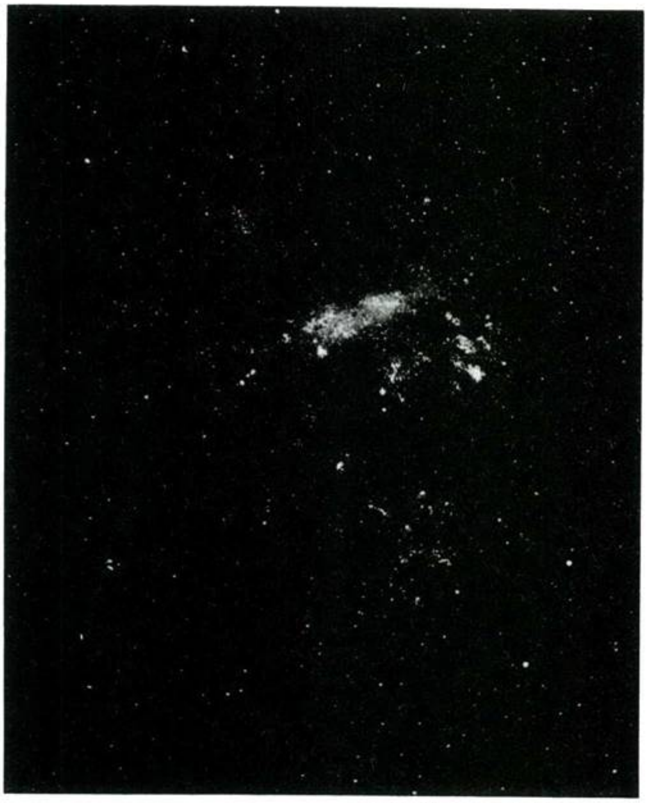
Only tiny amounts of UV light ever reach Earth's surface because a protective shield of ozone gas in the atmosphere's highest layers absorbs most UV energy coming from the sun. Small quantities do penetrate, however, causing sunburn in humans and helping plants in photosynthesis. This absorbing layer of ozone has prevented astronomers from studying UV light from the sun or distant stars and galaxies — at least until suitable telescopes could be lifted above Earth's atmosphere on rockets or satellites.

The first UV astronomy was conducted after World War II with primitive devices on some captured German V2 rockets. But not until the 1960s did UV observations really begin, although they were mainly confined to solar research. NASA's 1968 launching of the first Orbiting Astronomical Observatories at last put UV telescopes above the atmosphere for more than a few minutes at a time. And a recent satellite named Copernicus has provided the

Blazing like a bursting 4th of July aerial display, the supergiant star Zeta Puppis ejects huge amounts of gas at millions of miles per hour. Zeta Puppis belongs to a mysterious family of 69 so-called P Cygni stars that all explosively boil off star stuff into interstellar space. Because P Cygnis are all very hot blue stars burning at surface temperatures approaching 60,000 degrees, much of their energy radiates in the spectrum's ultraviolet region. Through observing the UV light, astronomers can determine the chemical makeup of the hurricane-like solar wind blasting away from these stars.

Artwork by Adolf Schaller





Lick Observatory Photograph

This is a comparison of the Large Magellanic Cloud (LMC) as photographed in ultraviolet light from the surface of the moon by Apollo 16's Far-UV Camera/Spectrograph (upper) and in visible light with a ground based astronomical camera (lower). The bright central bar in the LMC, consisting of mostly relatively cool stars in the sun's temperature range, appears prominently in visible light but is hardly evident in the far-UV. Hot blue stars in the LMC's outer regions are very faint in visible light but glow much brighter in ultraviolet.

most detailed knowledge to date about the spectrum's UV portion.

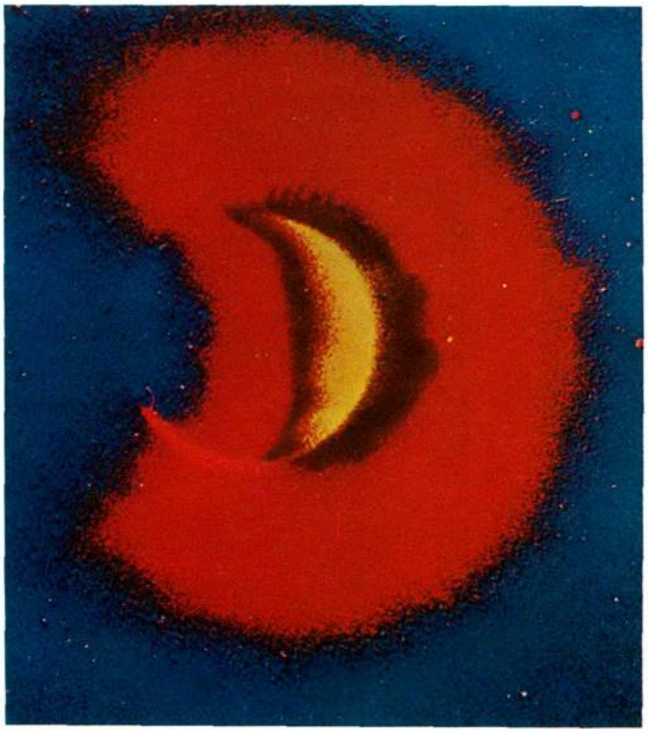
Through examining UV light, astronomers can learn not only about the chemical composition of a star's outer atmosphere but also about the kinds of elements making up gases floating in interstellar space. But how can studying UV light and other forms of electromagnetic energy tell us about chemicals that are countless light-years away? The atoms in interstellar clouds block out certain wavelengths of starlight heading toward Earth. Atoms of each element in the cloud absorb only a specific wavelength or set of wavelengths, giving every element its own unique absorption pattern — as individual as your Social Security number. The pattern shows up as a series of dark lines overlapping a star's spectrum.

Many interstellar elements' "spectral signatures" appear only in the UV area. The first detailed discoveries include such basic atomic building blocks as oxygen, nitrogen, carbon, magnesium silicon, phosphorous, sulphur, iron and titanium. Among the most exciting discoveries is that of molecular hydrogen (consisting of two hydrogen atoms) — long suspected but only detectable in UV — and molecular deuterium (one hydrogen atom and one deuterium atom). Comparing amounts of these two chemicals in the direction of the star Beta Centauri has given us new insights into the creation of the universe.

Our universe, according to the theory now most popular with astronomers, was born from the explosion of a huge, superdense ball of neutrons called the "cosmic egg". In the first few chaotic instants of the "big bang", this concentrated matter disintegrated into individual neutrons — many of which further broke apart into electrons and protons. In turn, electrons and protons paired off creating the newborn universe's first and most abundant element — hydrogen. If the temperature of the big bang was high enough, some protons forming the nuclei of hydrogen atoms fused with free floating neutrons, transforming a percentage of hydrogen into a new and heavier element called deuterium.

By estimating the amount of hydrogen that was turned into deuterium, astronomers hope to answer one of the most naggingly fundamental questions confronting modern astrophysics: How much matter exists in the universe? If the cosmic egg was very dense, then most deuterium should have taken on additional electrons — turning it into helium. Conversely, the lower the egg's density, the more deuterium we should see.

Through UV observations astronomers have found 70,000 times as much hydrogen as deuterium in interstellar clouds. From this ratio they calculate that if you evenly spread out all the matter in the universe you'd find one hydrogen atom in every 3,000 cubic feet of space. These results say that there is not enough matter to gravitationally "glue" the universe together; instead, the galaxies should continue flying apart from each other indefinitely. But if the



NASA Photograph

An Apollo 16 far-ultraviolet photograph of Earth shows a hydrogen geocorona extending more than 50,000 miles into space. Originally taken in black and white, the picture is color enhanced to bring out additional detail. The spike at the lower left identifies auroral activity over the south magnetic pole.

universe was 27 times more dense than the deuterium calculations indicate, it should be gravitationally closed. The mutual gravitational tug of every galaxy upon every other one would continually slow down the expansion rate until the galaxies stopped for an instant, and then slowly began falling back toward ultimate collision with each other.

But these calculations presuppose that deuterium was only created in the big bang and not some other way. If other forces are still pumping deuterium into space, then the hydrogen/deuterium ratio is giving us a false picture of the chemical events during the cosmos' fiery birth. No one has yet come up with an alternative for making deuterium, although observations of the speeds at which very distant galaxies are receding from us suggest that the universe is really gravitationally closed — the opposite of the UV results.

Besides gas, huge clouds of dust inhabiting the vast gulf between stars also absorb incoming starlight giving us clues about what kinds of chemicals make up the dust. Visible light is usually reddened as fine dust particles scatter the bluer, shorter wavelengths, and UV light gets attenuated in similar ways. Comparison of how visible and UV light are affected by their collisons with interstellar matter has revealed silicon and graphite as two constituents.

Apparently interstellar dust clouds have distinctly different types of particles even within one cloud; in some regions of space one particle predominates, while other types of particles are more common in another region. Some astronomers speculate that the nature of a given dust cloud depends on what types of stars have shed matter into it.

An especially exciting surprise was the discovery of interstellar clouds roasting at temperatures ranging from 100,000 to 1,000,000 degrees. Their existence is inferred from observing characteristic UV signals from highly ionized oxygen. Astronomers previously thought that interstellar matter was much cooler — seldom rising above the 100 degree mark.

Besides revealing the existence of elements in space, UV data from Copernicus cast new light on the so-called P Cygni stars — usually very hot and luminous supergiants having large quantities of matter streaming away from them. A typical P Cygni star might throw off a whole sun's mass in less than a million years. Commonly called the solar wind, this matter hurls outward fast enough (almost six million m.p.h.) to escape back into interstellar space. Our sun also injects small quantities of matter into space, but comparing it with a P Cygni star would be like comparing a trickling faucet to Niagara Falls. UV proves an excellent region to clearly observe superhot atoms blowing away from the star.

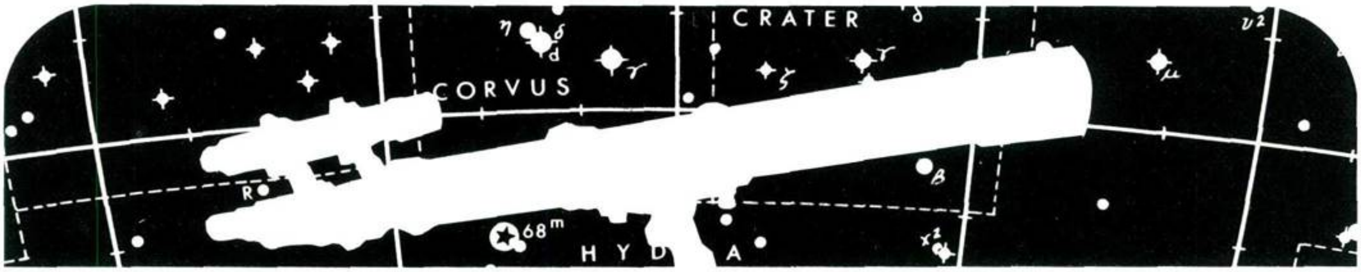
Observations made on the Apollo 16 moon landing are among the most recent milestones in UV astronomy. An ultraviolet camera carried on that mission photographed Earth, the sun and various star fields as well as our neighboring galaxies, the Magellanic Clouds.

Earth's pictures were particularly spectacular because the hydrogen gas surrounding our planet radiates in UV and cloaks Earth in a "geocorona" — much as the solar corona surrounds the sun. Being the lightest of elements, hydrogen in Earth's atmosphere extends almost 60,000 miles into space.

By measuring UV airglow scientists learn how solar energy is distributed as it falls on the atmosphere, and also can detect small amounts of particular gases. Atoms of many gases in Earth's atmosphere absorb and re-radiate only certain ultraviolet wavelengths of sunlight. Just as interstellar gas has its own special signature, so do gases surveyed in our atmosphere — except that by taking a UV spectrum in this case we'd find bright emission lines in an otherwise dark spectrum.

It is always exciting to live at a time when a new field of astronomy is suddenly born, opening up another window to the universe. This is especially true in the case of UV astronomy — where the biggest surprises are yet to come.

Dr. Verschuur is a regular contributor to ASTRONOMY. He is director of the Fiske Planetarium and a professor in the department of astrogeophysics, both at the University of Colorado in Boulder. In addition to over 50 published scientific articles, he has contributed "The Interstellar Medium" to the 1973-74 edition of **Encyclopaedia Brittanica** *and is author of* **The Invisible Universe** *(Springer-Verlag, New York, 1974), a layman's introduction to radio astronomy.*



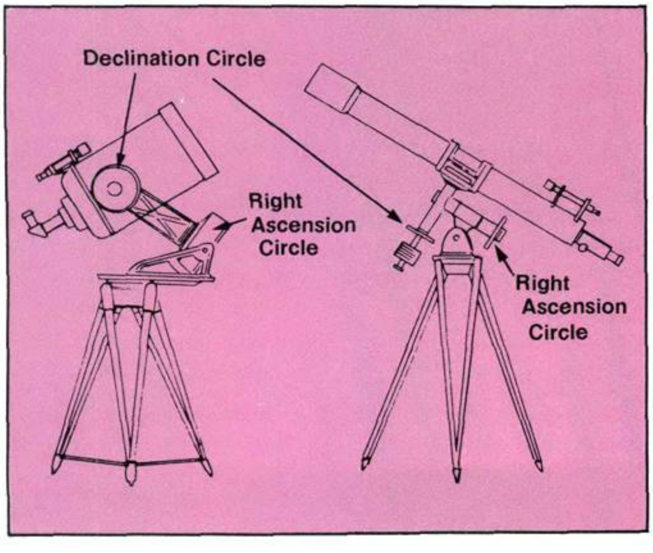
EQUIPMENT ATLAS

Getting to Know Your Telescope

Part 2: Setting Circles

Some of our readers can rapidly set up portable telescopes, line them on the north celestial pole, and then turn almost instantly to something invisible to the unaided eye such as a faint cluster of stars known as M-35. For such experienced observers an introduction to finding sky objects is unnecessary. But for those of us who can't rapidly accomplish it, such a feat seems magical.

"Is there an easy way to find objects that are seemingly buried in the myriad of stars overhead?" you ask. "Would those little dials with numbers on them (setting circles) that are on my telescope mount help me out in finding something that may take me hours to find by studying star charts?" Well the answer to the first question is no, and the answer to the second one is possibly. However, we should find out what those little numbered dials will do and whether they are worth using in particular circumstances.



There is the example, and it's quite common, of the beginning astronomy enthusiast — maybe you — who has never really examined the sky even though he has a small telescope. Then he reads on the other pages of this magazine about viewing Saturn and examining its rings through a small telescope. The novice also may read of the jewel box appearance of some star cluster in the constellation Gemini. A strong desire to go out tonight, set up the telescope, and find these objects is submerged by the unfamiliar sky.

Admittedly there is a big difference between finding Saturn and locating the star cluster M-35. Both of them are in the constellation Gemini — one dazzlingly bright and the other obscurely faint (a good photo of M-35 is on page 56). The problem for the true beginner is that he can't find Gemini, and therefore can't find either of these objects. If you are in this position, our immediate recommendation is to forget about setting circles and forget about those crazy lines on our charts that are numbered in hours and degrees (that's the celestial coordinate system — the address that each object has). Worrying about these before you can find the constellation is like worrying about whether your car has bias belted or radial tires before you learn how to drive.

Our point is this: You must have a working knowledge of the major constellations and be able to locate the brighter planets before you can go on to comprehend and make use of the celestial coordinate system and your setting circles. We cannot emphasize this point too strongly. It may seem easy to go out, set up your telescope, dial coordinates on the two circles and point your telescope. This is really the hard way to observe. On rare occasions, observers have survived without knowing any constellations and yet are able to locate objects below naked eye visibility by using setting circles. However, this is most uncommon and virtually all experienced observers will not suggest taking that route. It's like going on a vacation trip with a bag over your head. When you come to a specific spot you take the bag off, look at the scenery, and then put it back on until you drive 50 miles farther on. If the trip is worth taking, the scenery is probably worth looking at. In the same way, the search for a celestial object is often just as rewarding as observing that object.

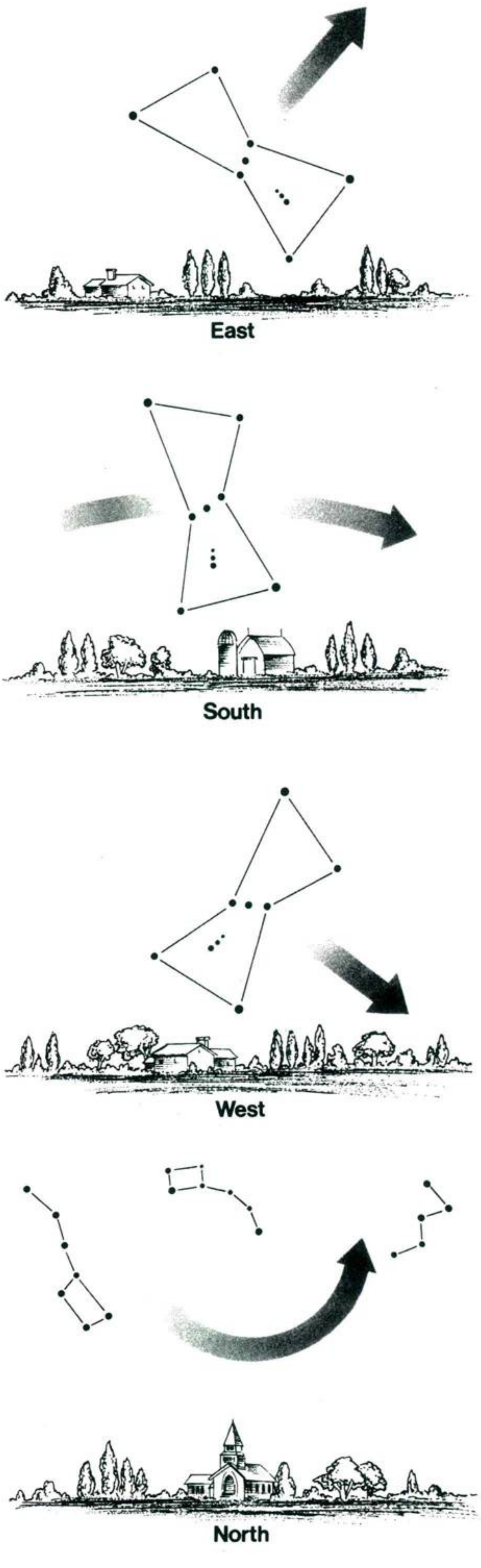
Let's make the following assumption: You have observed the sky enough to be able to locate the major constellations; stars such as Rigel and Capella are not unknown to you and you are able (perhaps with the help of a star chart) to point to them readily. Saturn is easily identified and you have looked at it with your telescope. But suppose you want to find M-35 in Gemini. The easy way is to use the chart on page 70 or some other fairly detailed star chart. This is the method of going from the known to the unknown. That is, point your telescope at the nearest star that you are familiar with and then move, by the use of a star chart, from one adjacent star field to another until you've reached the object that you are interested in. This is precisely the reason why we include the detailed Star Dome maps each month.

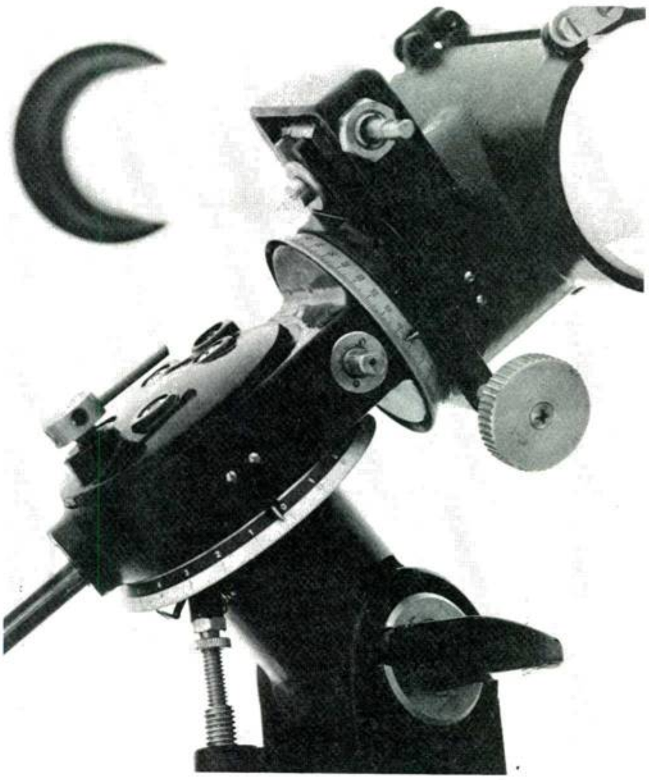
However, in an area of the sky like the region around the constellation Cancer, there are not many bright stars to do the guiding and the use of setting circles will maybe be just as easy as fumbling from star to star. This is a particularly debatable point. Many experienced observers such as Tom Bretl and Jim Mullaney who have prepared detailed descriptions of deep sky objects for ASTRONOMY say that they prefer the known to the unknown method since it increases your familiarity with the sky the more you use it. Frequently you bump into something almost as interesting as the original objects that you were looking for. Telescope observing can become a sequence of new discoveries each night.

You may say, "I've tried that method and for me it's a sequence of frustrations. I'm never able to find anything except the brighter objects." This may be partly due to your location. Urban dwellers are more often setting circle users than rural observers, and there certainly are times when setting circles can be exceedingly useful — such as in periods of bright twilight when you wish to find Mercury or Venus before the sky gets dark. These two planets can also be observed during full daylight but the only practical way to find them is with setting circles. However, these are rather specialized cases that we will deal with in a future article. Let's talk right now about the application of your setting circles to night observations. To do this we need some background on the celestial coordinate system.

The celestial coordinate system can be easily

Apparent Sky Motions





The telescope's right ascension circle, calibrated in hours and minutes, is attached to the polar axis (the one that points to the celestial pole). The R.A. scale is movable and can be set by observing a bright star as described in this article. The declination circle is marked in degrees and is fixed in position. This three inch refractor's circles read to an accuracy of about 1/2 degree declination or five minutes right ascension. Larger instruments usually have circles that give greater accuracy. In general, astronomy enthusiasts with small telescopes do not make much use of setting circles.

visualized if you imagine all the objects in the sky as points on a gigantic sphere whose center is the location of Earth (diagram, page 42). In this concept we are living on a sphere within a sphere. Let's now suppose that the lines of latitude and longitude that exist on Earth are extended into space until they touch the great celestial sphere. If you are standing at 40 degrees north latitude and 75 degrees west longitude that same intersection of points would be exactly over your head. We've simply extended the coordinate system of Earth into space. Thus all of those stars stuck on the sphere would have specific coordinates, just like each point on Earth has its coordinates. Just as any place on Earth can be located by its longitude and latitude, any place in the sky can be located by its celestial longitude and latitude.

Latitude on Earth and latitude in the sky are exactly the same except for their names. Sky latitude is called *declination.* Just as Earth latitude goes from 0 degrees at the equator to 90 degrees north at the north pole, and from the equator to 90 degrees south at the south pole, declination extends from the celestial equator to 90 degrees north at the north celestial pole and south from the celestial equator to 90 degrees south at the south celestial pole. These two systems are therefore exactly the same and present no problem at all. However, longitude is somewhat different.

On Earth, longitude is calibrated west from the Greenwich meridian halfway around Earth (180 degrees) and east from the Greenwich meridian the same amount until they meet at the international dateline. In the sky, celestial longitude is called *right ascension* and only goes in one direction. It is calibrated east in 24 divisions called hours. So instead of having "15 degrees east celestial longitude", the sky system has "one hour right ascension". Thirty degrees east is two hours R.A. (right ascension is often abbreviated). Don't worry about the point at which the 0 hour coordinate originates — it's not important for our discussion.

We have now established the basic differences between the Earth and sky coordinate systems. Things would be extremely simple if Earth didn't rotate; above you in the same position every night would be the same celestial object (except for the few objects that move, like the planets). Unfortunately such simplicity is denied us. The whole sky seems to move because Earth is rotating from west to east. As you can see in the diagram on page 42, Earth's rotation from west to east would make the sky seem to appear to move from east to west and, of course, this is exactly what happens. The sun rises in the east, moves across the sky and sets in the west — and so does every other celestial object. The whole sky appears to complete one rotation during the time it takes Earth to actually complete one rotation on its axis.

This rotation affects only one set of coordinates in the sky coordinate system. The declination lines (the ones similar to the lines of latitude on Earth) do not change. The sky declination of +40 degrees will always be straight overhead if you live at 40 degrees north latitude. Whatever your latitude, the same reading of declination will be straight overhead. All other declinations will be at the same elevation above the horizon at all times as long as you don't change location.

Celestial coordinate changes occur in only right ascension. It is for this reason that the declination circle on your telescope is relatively simple to use. Once your telescope is polar aligned the declination circle simply corresponds to the imaginary grid of declination lines in the sky. If you dial 90 you'll point to the north celestial pole; if you dial zero your telescope points to the equator; if you dial 35 degrees north, it points to that declination regardless of what time of night or what day of the year it is.

However, it takes two coordinates to locate a celestial object. If you dial 12 hours 46 minutes on the right ascension circle you could be pointing to a place in the sky that does not correspond to that right ascension. Earth's rotation constantly changes R.A. so you'd have only a slim chance of being right. To get around this you will probably find that, unlike the declination circle, your right ascension circle is movable.

Declination Circle Check

Usually a telescope's declination circle is set at the factory and requires no adjustment for the lifetime of the instrument. To check to be sure your declination circle is accurately aligned, set up as usual with the scope's polar axis adjusted to within a degree or two of the north celestial pole (for instructions see Equipment Atlas, January 1975). Then turn your telescope to a star in the south near the celestial equator (consult Star Dome for star selection). With the star in the center of the field of a high power eyepiece, read your declination circle as accurately as you can. Then "flip" the telescope. To do this, turn the telescope in declination so that it now points directly away from the star you were just looking at. Now turn the scope on the other axis — the polar axis — until it is around the right way again. It should be generally aiming back at the same star you were just observing. Center the star again in the high power eyepiece and read the declination circle. It should read the same to within a degree. If it doesn't, then split the difference between the two readings. Loosen the declination circle so that it can be adjusted to read the mean between the two figures that you recorded. For example, if the star that you selected read +2 degrees on the first view and after you flipped the scope it read +4 degrees, then you should adjust your declination circle to read three degrees. Then repeat the experiment. The declination circle should now read three degrees for both positions. With a Newtonian telescope this procedure can only be carried out on a star on the celestial equator fairly close to due south because of the access limitations of the mount when going from one side to the other for the flipped position.

Your declination circle is now fixed in its working position. Hopefully no adjustment was necessary but it's worth checking to save future frustrations.

To see how this movable feature is utilized, let's try to locate an object using our setting circles. We'll try for M-35 in Gemini; right ascension 6 hours 7 minutes, declination +24.4 degrees (declination is often given in degrees and minutes but this exceeds the accuracy of most setting circles).

BRIGHT STAR COORDINATES

Star Name	Designation	Right Ascension	Declination
Alpheratz	Alpha Andromedae	00^h06^m	+28.9°
Caph	Beta Cassiopeiae	00^h07^m	+59.0°
Deneb Kaitos	Beta Ceti	00^h42^m	-18.1°
Aldebaran	Alpha Tauri	04^h34^m	+16.4°
Rigel	Beta Orionis	05^h13^m	-08.2°
Capella	Alpha Aurigae	05^h14^m	+45.9°
Betelgeuse	Alpha Orionis	05^h53^m	+07.4°
Sirius	Alpha Canis Majoris	06^h43^m	-16.7°
Castor	Alpha Geminorum	07^h32^m	+31.9°
Procyon	Alpha Canis Minoris	07^h37^m	+05.3°
Alphard	Alpha Hydrae	09^h26^m	-08.5°
Regulus	Alpha Leonis	10^h06^m	+12.1°
Dubhe	Alpha Ursa Majoris	11^h01^m	+61.9°
Denebola	Beta Leonis	11^h47^m	+14.7°
Aloith	Epsilon Ursa Majoris	12^h52^m	+56.1°
Spica	Alpha Virginis	13^h23^m	-11.0°
Arcturus	Alpha Bootis	14^h14^m	+19.3°
Antares	Alpha Scorpii	16^h27^m	-26.4°
Rasalhague	Alpha Ophiuchi	17^h33^m	+12.6°
Eltanin	Gamma Draconis	17^h55^m	+51.5°
Vega	Alpha Lyrae	18^h35^m	+38.7°
Altair	Alpha Aquilae	19^h49^m	+08.8°
Deneb	Alpha Cygni	20^h40^m	+45.2°
Fomalhaut	Alpha Piscis Austrinis	22^h56^m	-29.8°

This table lists 24 widely dispersed bright stars that can be used to set the right ascension scale on your telescope. *Select the star nearest the object you plan to locate by* setting circles.

Remember, your setting circles won't do you a bit of good unless your telescope is properly polar aligned. Complete instructions for achieving such alignment were given in last month's Equipment Atlas. Assuming your telescope is polar aligned to within a degree or so of the north celestial pole — this is accurate enough to make the setting circles useful for most applications — check to make sure your declination circle is calibrated properly. Instructions for this are in the box on this page. This should have been done at the factory but it takes only a few minutes to check it out.

Finally all the preliminaries are out of the way and we can now use the setting circles. Point your telescope at some bright star in the same general area of the sky as the object you want to examine. Since we are looking for M-35 we will select Castor in Gemini. By consulting the list on this page we see that the right ascension of Castor is 7 hours 32 minutes, declination +31.9 degrees. The next step is to turn the movable right ascension circle so that it reads 7 hours 32 minutes. Because the declination circle is fixed, it should already read close to +31.9 degrees. We can now "dial direct" to the reading of M-35: 6 hours 7 minutes right ascension and 24.4 degrees declination. M-35 should now be within the finder field of view and, depending on the accuracy of the circles and polar alignment, it may be visible directly in the telescope using the lowest power eyepiece.

That's all there is to it. With practice you should become very adept at using this system.

There is one more thing to check. On some tele-

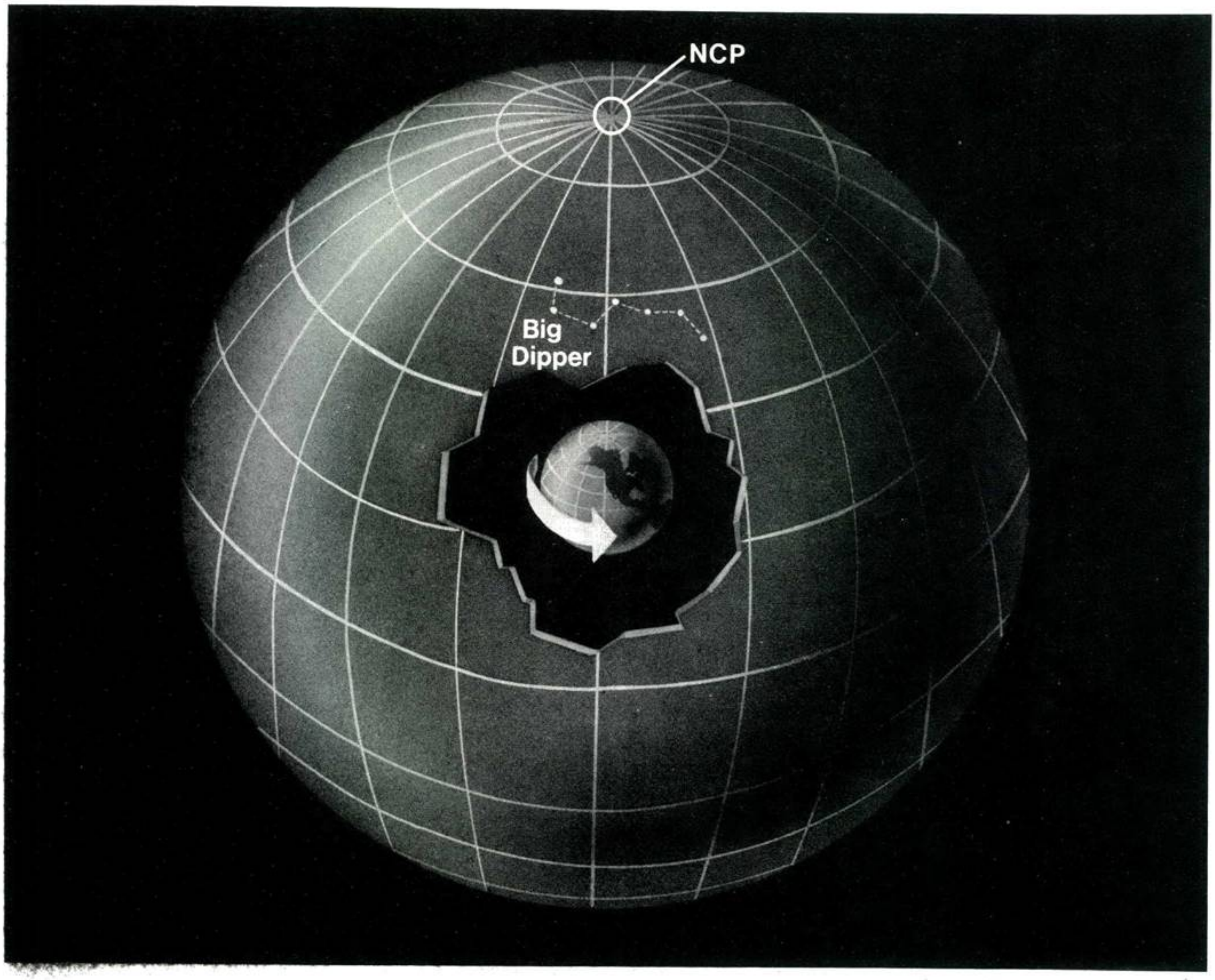


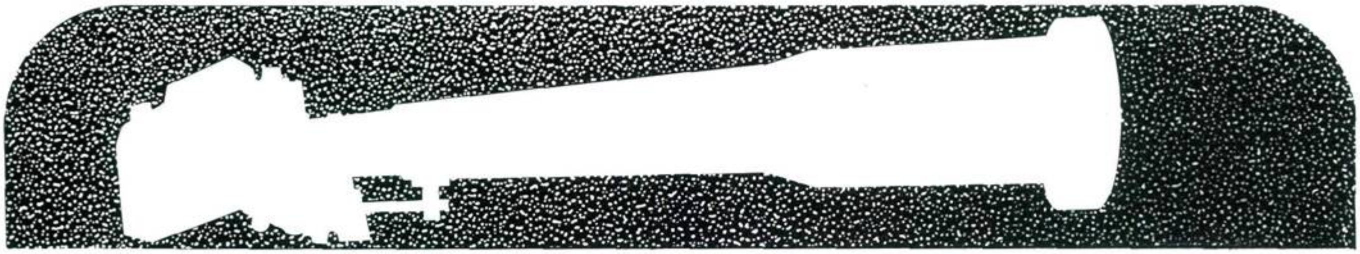
Diagram by Victor Costanzo

All sky objects can be imagined as being attached to a colossal sphere that we view from inside. Earth's rotational axis extends to the sphere at the north celestial pole (NCP) and the south celestial pole (not visible here). To us on Earth, the sky seems to move opposite our direction of rotation. As this occurs, the grids of right ascension sweep by in endless procession.

scopes the electric clock drive also drives the right ascension circle. If yours does, you are lucky. Once you have set the scope on a star, as we did with Castor above, then it will remain set for the rest of the night provided the electric drive remains on. Your setting circles will turn very slowly if the drive is operating them. Otherwise you have to return to a star on our list and reset the right ascension circle according to that star's R.A. before you'll go to search for another object. Sky rotation will soon give your R.A. circle a reading other than the true sky coordinate simply because Earth is rotating your telescope away from its original setting. Many moderately priced telescopes do have the right ascension circle linked up with the clock drive, so the convenience of using setting circles is greatly increased.

One thing that this method requires is a working knowledge of the constellations. You still have to point your telescope at a bright star to get started and you definitely must know the name of that star so that you can check it on the list and set your right ascension circle. There is an alternate and more complex method for setting the right ascension circle without knowing the names of any stars, but this is mainly used by advanced amateurs with domed observatories where there is only restricted opportunity to select stars at random. Usually someone with a setup like this knows the sky well enough to be able to use an advanced technique without jeopardizing his learning experience.

Another point of confusion concerns the lists of celestial objects' coordinates that appear in various handbooks and star atlases. They may be labeled "1950 coordinates" or "1975 coordinates". A ponderous wobbling of Earth called precession is responsible for a constant, but exceedingly slow change in right ascension and declination. For all practical applications, the change is so slight that the astronomy enthusiast can ignore the difference. The grid systems and coordinate lists in ASTRONOMY or anywhere else can all be considered to have the same base.



The Night Tourist

by
Von Del Chamberlain

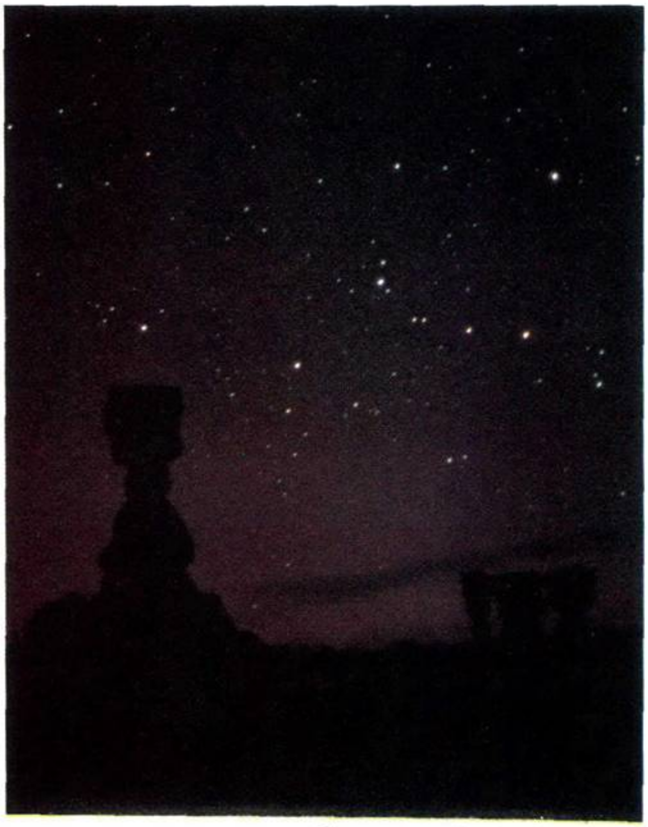
In forgotten ages, our ancestors developed a tradition which has become an accepted way of life even to the present. As the reassuring warmth of daylight gave way to the chill of evening, they entered caves and other dwellings to huddle together, barricading eyes and mind against the strangeness of the night. Each night they died a little to live again with the new dawn. Routinely we repeat the ritual, and in so doing may close our minds to the perception of nature's most enthralling secrets.

We tend to be tourists by day, retiring early so that we're refreshed for a busy agenda of sightseeing and snapshooting the next morning. As the ruddy glow of twilight dissolves in darkness, so too does the gathering of others of our kind. They transport themselves away in metal clad capsules to their lighted chambers which give comfort to their minds, still subconsciously bothered perhaps by the ancestral fear of beasts and monsters lurking in the dark.

But we who read these pages should be at ease in darkness — so why not stay awhile to savor the night and capture what we can of our experiences on film. Stand sometime with others at Sunset Point in Bryce Canyon National Park (in southern Utah) to witness the glorious death of another day. Navajo Trail is soon deserted and we wander among the cliffs by starlight, cameras slung on shoulders, tripods gripped in hands. Pink cliffs lose their color and turn to silhouette against a sky now lit by the quarter moon. Great monoliths, wild creatures, grotesque creations of another world — whatever the mind desires could be imagined among the pillars enclosing us as we descend into the canyon with the deepening shadow of night.

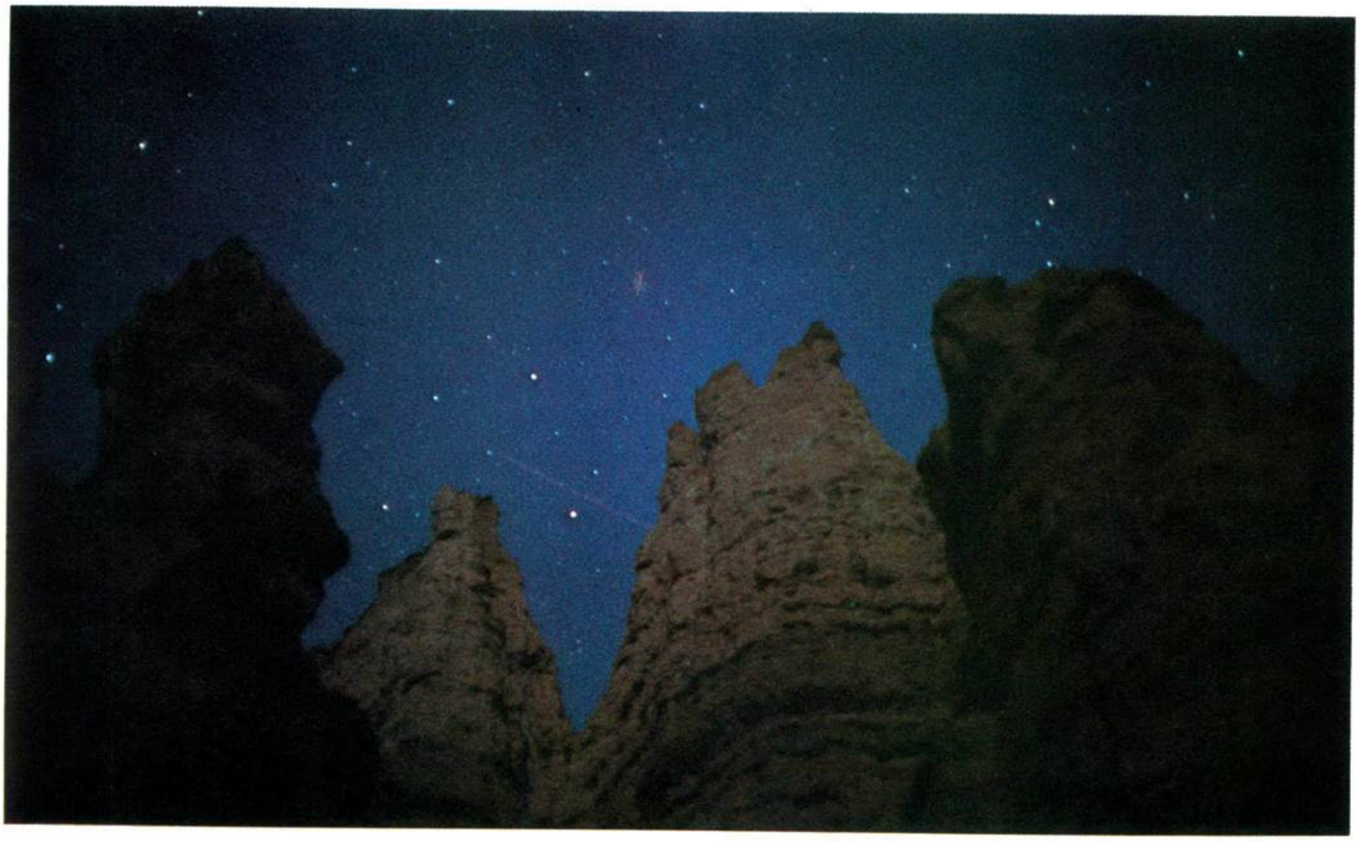
With minds tuned to both the encircling cliffs and stately stars beyond, we search the viewfinder for those special scenes of rock and sky to light-etch them on photographic film.

Soon ghostly lightning flashes bathe the canyon, followed by reverberating rumbles echoing from the walls. Expressions of dissatisfaction of the



Photograph by Von Del Chamberlain

As they have for centuries, the stars of Cassiopeia silently wheel above the natural pillar called Thor's Hammer in Bryce Canyon National Park. Long after this rock monument turns to dust, those same stars will still be shining — probably much as we see them today.



Photograph by Von Del Chamberlain

Dramatic nightscapes such as this are possible with standard photographic gear. A tripod mounted Cannon f/1.4 camera was left wide open for 25 seconds, followed by a strobe flash to illuminate the soaring walls of Bryce Canyon.

canyon gods? Frettingly we consider the possibility that our photographic expedition into darkness might be foiled. We do so much want to capture the moonlit cliffs in contrast to the gleaming distant stars.

Instead of hindering us, however, we learn that nature has merely decided to assist us with our hearts' desire. The storm passes near but never completely obscures the starry sky. A few soft clouds add interesting background for our photographic efforts, and lightning strobes the landscape during exposures. Finally, as the storm billows in the distance, we chance upon that once-in-a-lifetime photographic opportunity. Exposed to view of eye and lens is a scene of indescribable excitement. Nearby, Thor's Hammer stands against the distant flashing clouds, and above these gleam the sparkling stars. The accompanying photograph is a better description than words.

We are convinced that we are the only humans in Bryce Canyon that night. We share a precious experience, never to be exactly relived nor certainly to be forgotten. It is part of the web of our relationship with our own world and perhaps others in the firmament. On such occasions we learn the art of playing tourist in the night.

Perhaps the reader would like to join in fighting the inherited tradition, spawned in fear, and sample the sport of night tourism. Think about it. What has been the effect on human history of the simple experience of seeing the moonless, dark, clear sky under favorable conditions? How many people live their entire lives in our world without ever experiencing the dark night skies of the country? What percentage of human kind have never knowingly seen the Great Galaxy in the constellation Andromeda with their naked eyes? How many people spend time and other resources to visit great art museums, yet never think of planning time to journey into the country on a dark, clear night for the express purpose of enjoying the beauty of the sparkling, star-spangled sky?

Consider the words of Thomas Henry Huxley:

"To a person uninstructed in natural history, his country or seaside stroll is a walk through a gallery filled with wonderful works of art, nine-tenths of which have their faces turned to the wall."

Thor's Hammer, a prominent natural monument in Bryce Canyon National Park, is captured at a magical moment in this photograph. In Norse mythology, Thor — oldest son of Odin — was the strongest of the gods. He thundered across the sky in his mighty chariot and hurled his gleaming hammer which flashed out at his foes. Perhaps this rock prominence was named during a view such as this. The photo embodies many elements of nature that all ultimately had the same origin as described in this article. A tripod mounted Canon SLR camera with a 50mm lens at f/1.4 was used for this 25 second exposure during which time the lightning flickered adding the magic touch. The Kodak High Speed Ektachrome film was processed to ASA 400 for all photos in this article.

Photograph by Von Del and Blake Chamberlain

Apply this statement to the vast realm of the stars and contemplate the average blindness of the mass of humanity to the very existence of the universe. Why be part of the sightless mob? Instead, why not follow the unfulfilled, nagging urge to peer with growing comprehension into the universe?

Night tourism begins with the pairing of sensitive eyes and mind. Additional aids are the usual fine camera, a tripod, a cable release and the proper type of photographic film. The following suggestions should help in capturing photographic reminders of night experiences.

The camera should have a fast lens; a 50mm lens of f/2.0 or faster is a must. A tripod is required to steady the camera for exposures of at least several seconds. Highly sensitive film is needed to bring out features in subdued light. Fujichrome R100 (ASA 100), Kodak High Speed Ektachrome (ASA 160), GAF 200, or GAF 500 films work well. Experience is needed to learn to judge night lighting conditions — so as in all worthwhile photographic endeavors, don't hesitate to use a lot of film in "bracketing" for that rare shot.

Three basic techniques or combinations of them can be used to photograph landscapes with star fields: 1) photography can be done during twilight hours, starting as the stars become visible and lengthening exposures as twilight fades; 2) moonlit starscapes are perhaps the most successful, and 3) an electronic flash can be used to light nearby objects.

The exposure rule to remember with a 50mm lens is that 20 seconds will yield photographs without noticeable star trailing due to Earth's rotation. Aperture stops of f/1.4 to f/2.0 are required for starscapes within this period. Of course, exposures longer or shorter than 20 seconds can be used to achieve desired special effects.

The best night pictures require good composition of both foreground and sky background. Sometimes the background is the subject to be emphasized; sometimes the foreground is of central attention. Most night tourists seek photographs which tell stories of the intriguing activities and relationships of the natural elements around us. For example, a nearby familiar object which one could walk to and touch, juxtaposed against distant stars whose light has been traveling dozens, hundreds, or

thousands of years to stimulate our eyes and our photographic film, can produce an exciting photograph.

So why not try it the next time you visit a national, state or county park? Why wait until vacation time? On the next clear night why not take a drive into the countryside, locate a well shaped tree, and spend a portion of the night recording on mind and film the images of nature's miracles — the nearby mineral and biological forms together with the stellar energy and element-producing factories, the stars, which make such things — including us — possible. Why not become a tourist of the night?

A Red Window to the Sky

by Leo C. Henzl Jr.

If you own a clock driven telescope, you may already have tried "piggybacking" your camera on it for long exposure astrophotography. With the high speed films and ultrafast lenses available for 35mm cameras, this simple setup can be marvelously effective at recording faint detail in star fields, extended nebulae, and other celestial subjects of large apparent size.

Unless you live in a very isolated region, though, you may have found the effectiveness of your piggyback camera severely restricted by the fact that it records both sky objects and the glow of your nearby streetlight with an equal lack of discrimination. In populous areas, some of the most photogenic subjects are simply lost in the grayish murk of sky fog on your negatives.

What you need, then, is a "window" of a very special sort for your camera — one that admits light from celestial objects but excludes sky fog. Fortunately, in many cases there is a difference in the two kinds of light — color. Sky fog tends to be of a bluish hue, while many of the most spectacular of extended nebulae are predominantly red. Therefore, a #25 red photographic filter (such as you might use for darker sky renditions in black and white landscape photography) will pass much of the light from distant stars and nebulae, but block most of the scattered sky light at your location. As is shown by the comparison North American nebula photos reproduced here, the red filter yields greatly enhanced contrast between the sky background and the actual object itself.

To execute this technique, you'll need a special film sensitive to the red light that your #25 filter admits. Ordinary fast films such as Kodak Tri-X are not especially effective at recording red light, and thus suffer a significant speed loss when filtered in this manner. The answer here is Kodak 103aF, a special purpose film designed specifically for long exposure photography. In addition to providing the color sensitivity you need, 103aF also exhibits far less reciprocity failure than any ordinary emulsion, and so is vastly superior at recording extremely dim celestial objects — with or without filtration. You won't find this film at your local camera store, but you can purchase it directly by mail in bulk rolls or 36-exposure cassettes from Optica b/c Company, 4100 MacArthur Blvd., Oakland, Calif. 94619.

Your window may also net you the unexpected fringe benefit of improved image sharpness. All camera lenses suffer to some extent from chromatic aberrations — the failure to bring all colors of light to precisely the same focus. The problem isn't especially serious in terrestrial photography, where stopping down to a typical shooting aperture yields the depth-of-field necessary to bring different colors of light to an approximately common focus. However, in astrophotography — where you generally use your lens at or near full aperture — the slight discrepancy in focus can mean highly aberrated star images especially near your field edges. The dramatic increase in sharpness in the accompanying red-filtered photos is probably the result of excluding unfocused light of various colors. We would expect some improvement with almost any camera lens, but exactly how much you gain will depend on how well color corrected your lens is in the first place.

By excluding most light near the blue end of the spectrum, a red filter will always reduce sky fog for a given exposure level on 103aF film — but it will not enhance contrast unless the object you wish to shoot emits a substantial amount of red light. This is the case with many of the subjects that lend themselves to piggyback photography, so you'll find no lack of projects to be undertaken through your red window to the sky.

Increased contrast and longer exposures are possible with the simple addition of a red filter over the camera lens. Photo at left is a 15 minute exposure on Kodak 103aF film developed in D-19 for four minutes at 70 degrees. More stars and new crispness in the North American nebula are obtained with the addition of a #25 filter over the 135mm lens (used for both photos at f/2.5). Because the red filter blocks out light that produces sky fog — that washed-out look — the right photo could be exposed for 30 minutes. With little to lose and much to gain, this is a combination that should be exploited by astrophotographers.

Photographs by Leo C. Henzl Jr.

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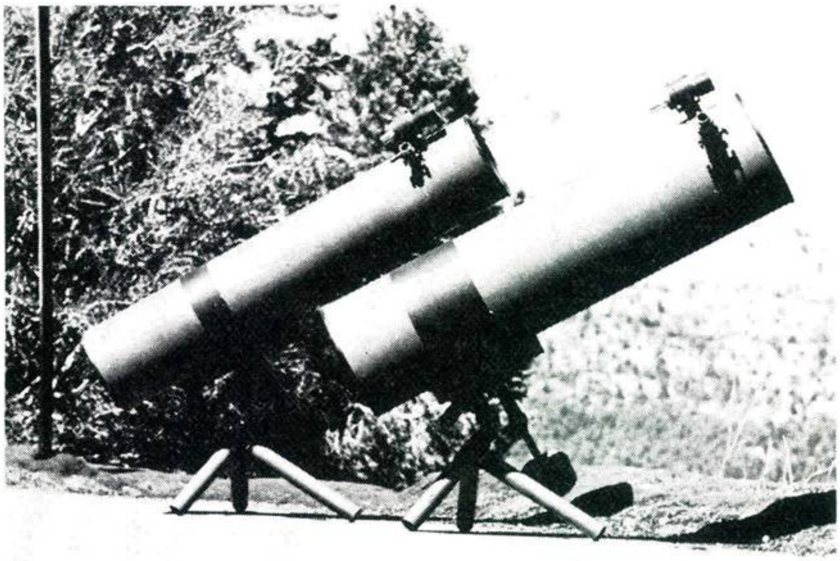

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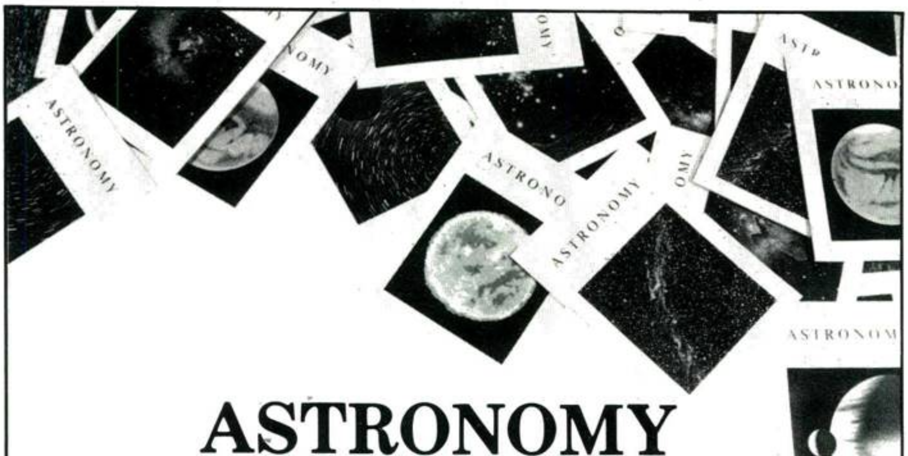

ASTRONOMY

Guide to Back Issues

Many readers continue to ask about the availability of ASTRONOMY back issues, but the majority blindly send us an order requesting issues we no longer have. For example, the October 1973 issue has been sold out for at least six months.

The following guide, which will be changed monthly, is designed to give you the most up-to-date information on the status of back issues. While they last, back issues are available for the cover price of $1.50 each (price includes postage).

When ordering, please clearly state quantity, volume, number, month and year for each issue (first issue was August 1973), and **include payment with your request.** If issues ordered are no longer available, unless you instruct us to forward a refund or substitute issues, we will automatically extend your subscription appropriately.

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Vol. 1, No. 4 - November 1973	Depleted	Vol. 2, No. 11 - November 1974	Available
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Vol. 2, No. 1 - January 1974	Short Supply	Vol. 3, No. 1 - January 1975	Available
Vol. 2, No. 2 - February 1974	Short Supply	Vol. 3, No. 2 - February 1975	Available
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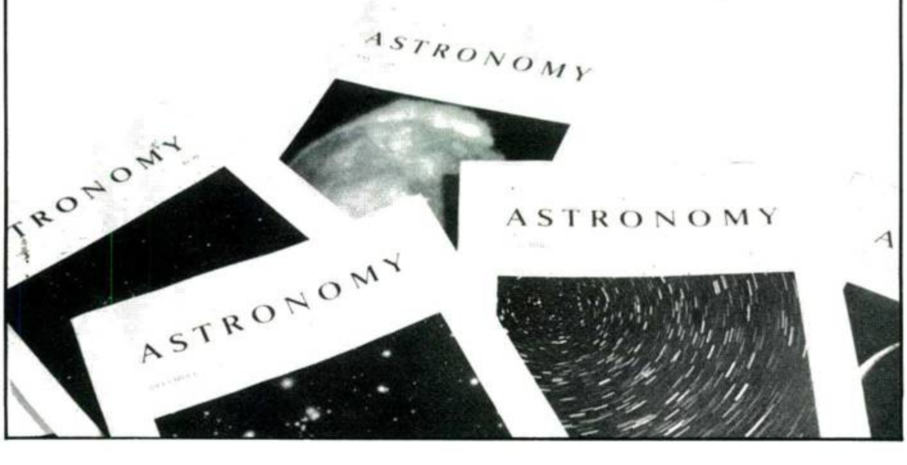

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Hunting Variable Stars

by
Leslie C. Peltier

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Anyone watching the skies over a long period of time soon realizes that the most interesting celestial sights are those showing activity and change. We intently gaze at a satellite's shadow creeping across Jupiter's broad expanse, and from year to year we observe the slowly tilting rings of Saturn. We note the vagrant wanderings of the planets moving among the stars, and follow the changing phases of the moon as it marches across the sky each month. Throughout the night we watch as the turning Earth brings a bright array of stars up in the east and drops others down below the western skyline. But there are even mightier changes taking place among these circling stars — strange happenings that you can watch without a telescope if you know just where to look.

Variable stars exhibit some of the most mysterious changes. You may already have found one of these stars during your perusal of the night sky. If you looked for it again some days or weeks later you may have found only a blank spot in the sky. That is the customary behavior of these strangely inconsistent stars.

Variable stars undergo changes in brightness completely dwarfing any cataclysm that ever happened on Earth or elsewhere in the solar system. For most types of variables the reasons behind their fluctuating brightness remain enigmatic. Let's take a close-up look at some well-known variable stars.

Algol (Beta Persei)

For countless centuries the star Algol in the constellation Perseus has regularly "winked" at earthly stargazers but hardly anyone noticed. In

1782 the young English astronomer John Goodricke suggested that Algol might be a double star: The main star of the system has an invisible companion star revolving around it which, at intervals of 2 days 20 hours 50 minutes, passes between Earth and the main star blocking off some of its light.

This is exactly what happens when our moon, revolving around Earth, passes between us and the sun causing a partial eclipse. Algol is therefore known as an eclipsing variable.

At full brightness Algol's magnitude is 2.2 (almost the same as Polaris). If you make a careful check each night, sooner or later you will see it wink. As the slightly luminous companion starts the partial eclipse, Algol's light diminishes — fading to magnitude 3.7 about 4-1/2 hours later. After remaining dim for about 20 minutes, its brightness sharply increases for another 4-1/2 hours as the darker star passes from between us.

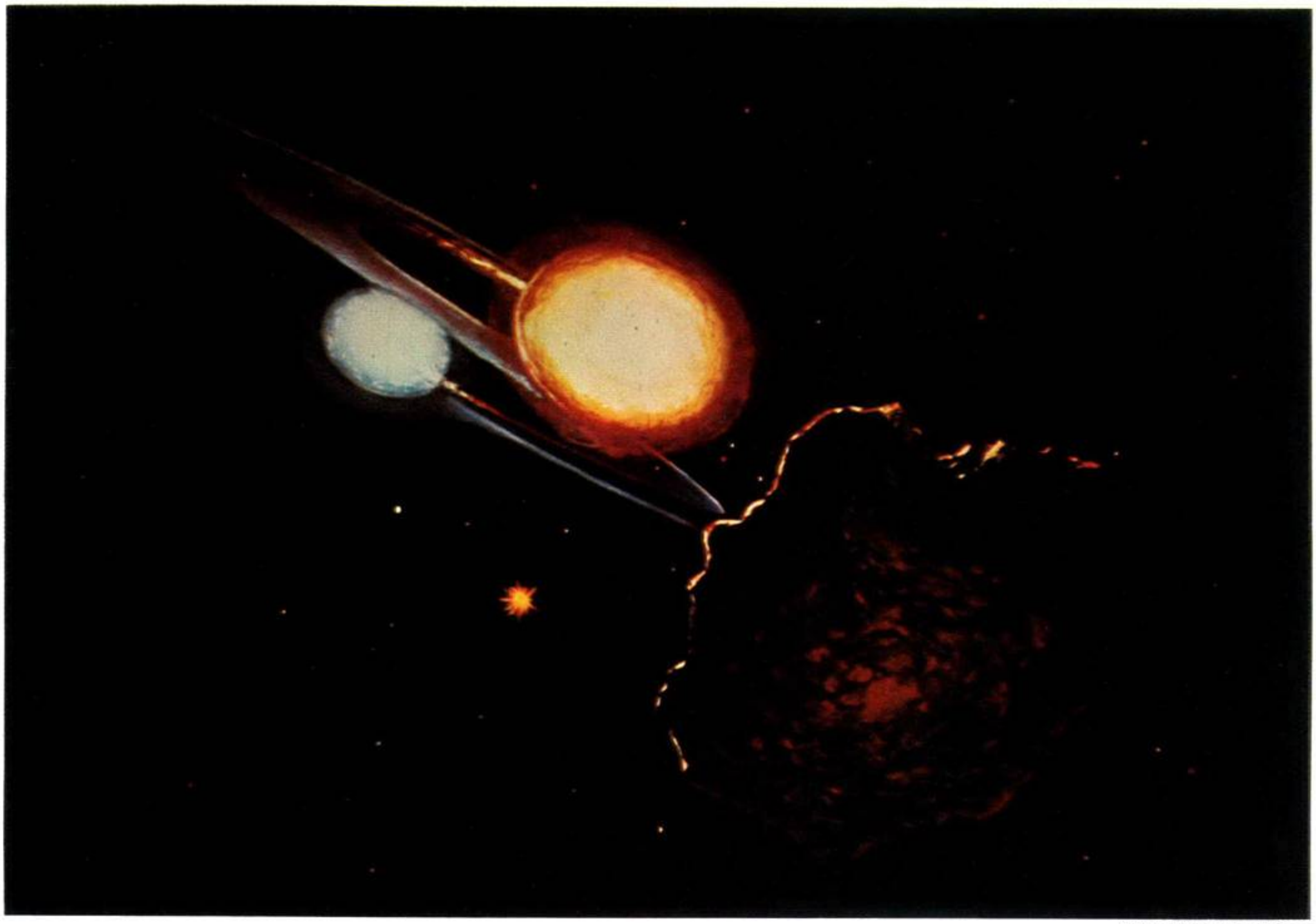
The illustration on page 53 shows graphically just what is taking place at all times. Note the sharp drop to minimum during the eclipse phase and also the equally rapid recovery. This is followed by a slight and gradual increase in brightness due to the added reflection of Algol's light on its unseen companion. Then brightness slightly drops in the middle of the cycle as the companion star, in turn, is eclipsed by Algol.

Since each of Algol's winks takes between 9 and 10 hours, it is often possible during the long autumn and winter nights to watch a complete cycle. Having once observed an eclipse and knowing the exact period, you can make your own schedule of future eclipses. Here are the times (all are EST) of mideclipse occurring during February evenings: 15th, 2:30 a.m.; 17th, 11:20 p.m.; 20th, 8:10 p.m., and 23rd, 5:00 p.m.

Algol lies 100 light-years from Earth, so remember that the changes you are watching occurred 100 years ago!

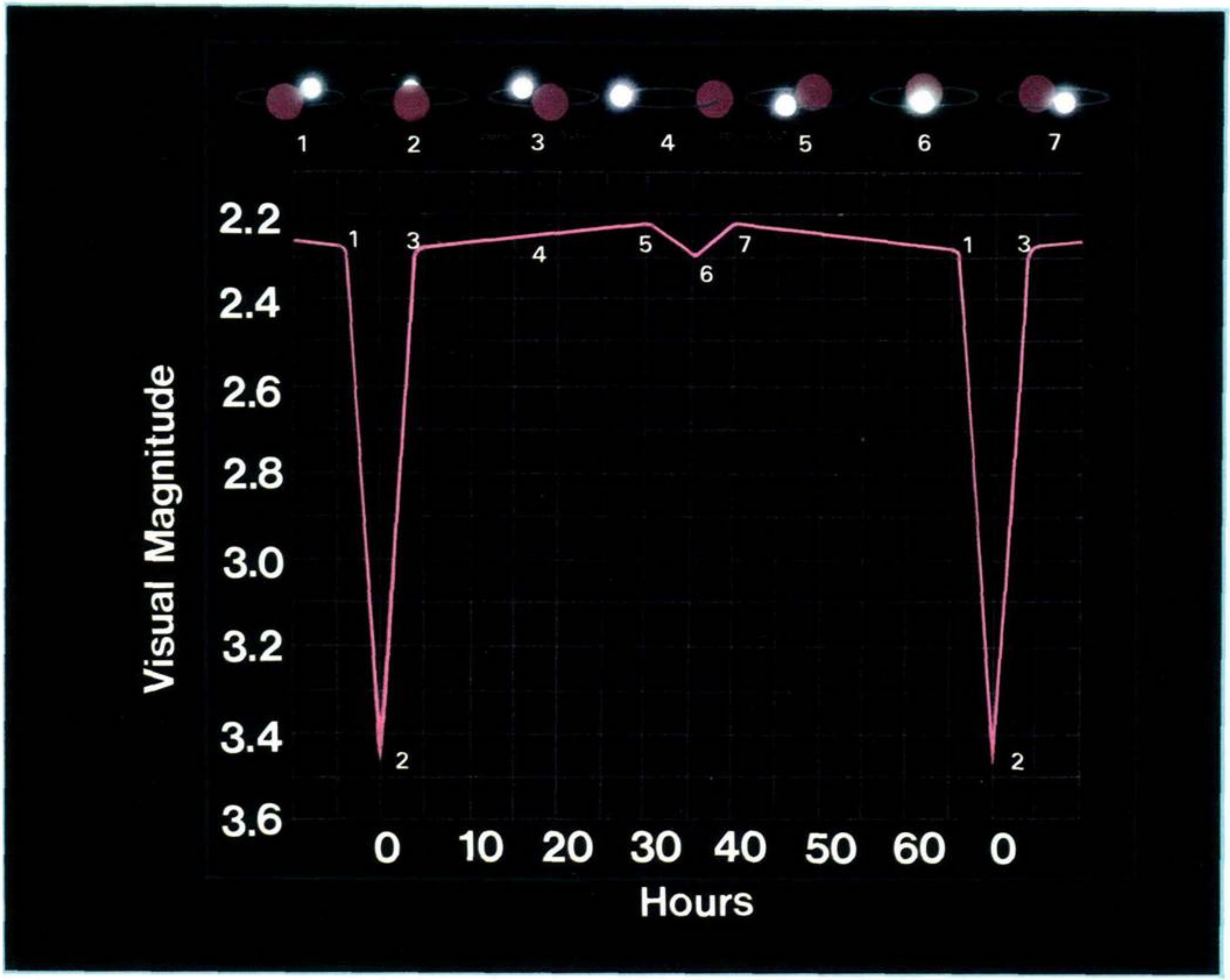
Delta Cephei

The star Delta Cephei is the prototype for a whole class of variable stars known as Cepheid variables, or simply Cepheids. Delta's variation seems to be caused by something taking place within the star itself — a process like a giant rhythmic pulsation or alternating contraction and expansion of the star. As the star shrinks it grows hotter and



Artwork by Don Dixon

The double suns that make up the star we call Algol whirl around each other in less than three days. The large star is the most massive of the two but is ominously losing its matter to the smaller star. The large star is the fainter of the two, perhaps due to the constant mass loss. The evolution of a star system like this is much more complex than the life cycle of a single star like the sun. The major light variations of Algol occur when the large dull star passes in front of the bright one.



Artwork by Victor Costanzo

The sudden drop in Algol's brightness that is observed from Earth every 69 hours is due to our vantage point that gives us a nearly edge-on view of this orbiting twin sun system. Seven positions of the bright and dull components of this double star are illustrated at the top. The variation in brightness is graphically displayed below. The numbers on the light curve correspond to the seven illustrated orbital positions of this eclipsing variable star.

brighter, and then grows cooler and fainter upon expanding.

After watching Delta for a few nights you will easily detect its variation. Delta forms a triangle with two nearby stars that are good for comparison. One night you may find Delta a little less bright than the fainter of these two stars, Epsilon, while a few nights later it may appear about the same luminosity as the brighter star, Zeta. Epsilon's magnitude is 4.2 while Zeta glows at 3.3 — a difference of nearly one magnitude between the two comparison stars. If Delta seems about midway in brightness between these two stars, you might record its magnitude as 3.7 or 3.8. If the variable appears only slightly brighter than Epsilon you could list it at 4.0, and when it is shining with almost the same intensity as Zeta, boost its rating to about 3.4. (Chart magnitudes exclude decimals.)

This briefly outlines the method for making visual estimates of star magnitudes. Delta actually ranges from about 3.5 to 4.4 in a period of 5-1/3 days.

Cepheids are often called the "yardsticks of the universe", because through studying them astronomers devised the period-luminosity law by which a star's distance can be determined. The law is simply based on the fact that the length of time a Cepheid takes to complete a cycle of variation is a reliable clue to the star's absolute magnitude, or true brightness.

For example, if the period is one day, the star glows 200 times as luminous as our sun. For a period of five days, the star is 500 times the sun's brilliance; if 10 days, the variable radiates at 800 times the sun's luminosity. By comparing a star's real luminosity with its apparent brightness as seen in the sky, the star's distance can be calculated.

Cepheids proved of great value when astronomers discovered them existing in remote globular clusters and galaxies, objects that previously defied all attempts at measurement. Now accurate determinations of periods and apparent magnitudes of individual Cepheids reveal the distance of the entire cluster or galaxy they inhabit.

Chi Cygni

Chi Cygni in the Northern Cross is classified among the long-period variables (stars having periods of 200 to 400 days). All long-period variables are red stars with light curves never repeating themselves precisely — either in period or range of brightness.

Chi Cygni's period lasts roughly 406 days — longer than most in its class. But its range extends greater than that of nearly any other star — from 4th to 14th magnitude. Since you cannot easily see stars fainter than sixth magnitude with the naked eye, Chi will probably be invisible when you first search for it. However, at some time each year you should be able to catch a glimpse of Chi and compare its brightness with the stars whose magnitudes are indicated in the diagram on this page .

With any long-period variable, the exact course it takes cannot be predicted. Chi occasionally reaches magnitude 3.5, while at other times it gets a little brighter than 6.0. These variations seem to occur entirely at random.

This year Chi is expected to reach maximum sometime in May (Cygnus will then be visible only after midnight). Try keeping your own record of Chi's brightness at each maximum together with the date of every observation. An estimate made each week during Chi's period of visibility should show when it reaches peak brightness.

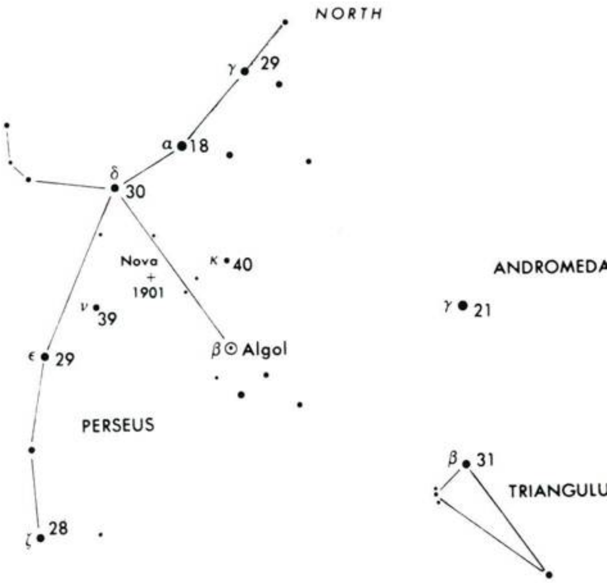
Mira (Omicron Ceti)

In August, 1596, German astronomer David Fabricus noticed a third magnitude star in the large but faint constellation Cetus. He had never seen a star in that position before, nor had one ever been charted there. During the following weeks it gradually faded and finally disappeared from view.

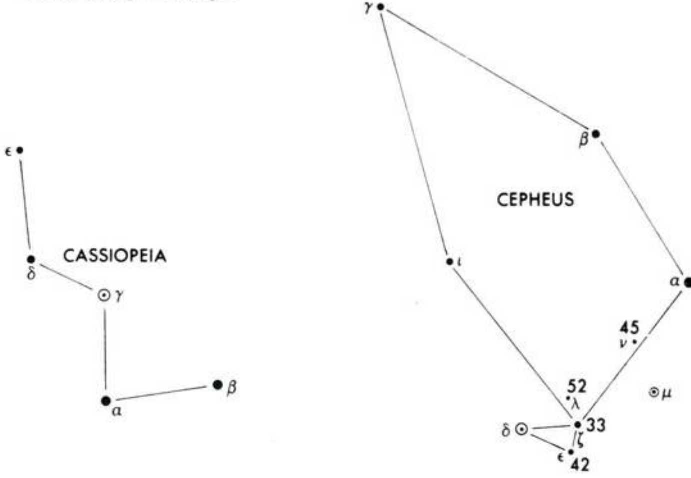
When the constellations were mapped in 1603 the star appeared again, and was designated Omicron. Observers soon noticed that the elusive visitor appeared in the same location about every 11 months, only to fade from sight again after a short time. Because of its strange behavior the star became known as Mira the Wonderful — the first variable star discovered.

Mira is a long-period variable (like Chi Cygni), ranging from second or third magnitude down to tenth magnitude. Mira's period from maximum to maximum usually lasts 11 months, varying by as much as a month. Although usually visible to the naked eye for six weeks during each cycle, sometimes Mira's maximum comes when the star is too close to our sun for observation. This year Mira is expected to reach maximum in early March while it is still visible low in the west after sundown.

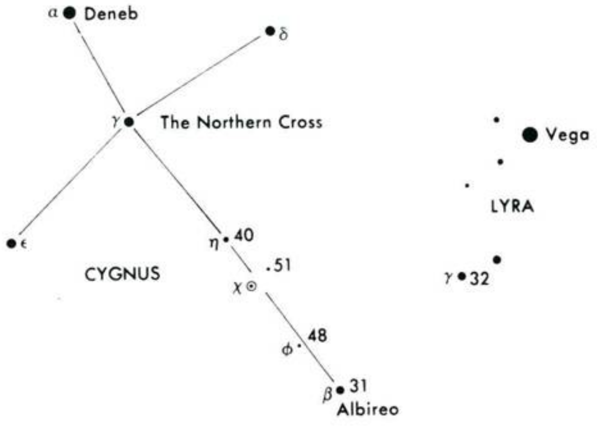
Since long-period variables are red stars, they



Algol, also known as Beta (β) Persei, is an eclipsing variable that abruptly drops from magnitude 2.2 to 3.5 in a few hours once every 2.9 days.



Delta (δ) Cephei is a pulsating variable that oscillates in a very regular rhythm between magnitude 3.5 and 4.4 during a 5.3 day period.



Chi (χ) Cygni is seldom visible to the unaided eye. This long period variable fluctuates between magnitude 4.0 and 14.0. Over 13 months separate times of maximum brightness.

are relatively cool. They are also giant stars — Mira being one of the real heavyweights, some 300 times larger than the sun. Having a density less than a thousandth of Earth's atmosphere, Mira (like Antares) might well be called a red-hot vacuum. The cause of variation in these long-period stars remains a mystery.

Gamma Cassiopeiae

The middle star in the bright "W" of the northern sky doesn't fit into any of the usual classifications of variable stars, so it winds up in an oddball group known simply as erratic stars.

Until 1936, Gamma was apparently a steady 2.2 magnitude star. Suddenly it began increasing in brightness until the following year it rivaled first magnitude Deneb in the Northern Cross. After slowly dropping to 3.0, Gamma then rose to 2.5 where it remains today.

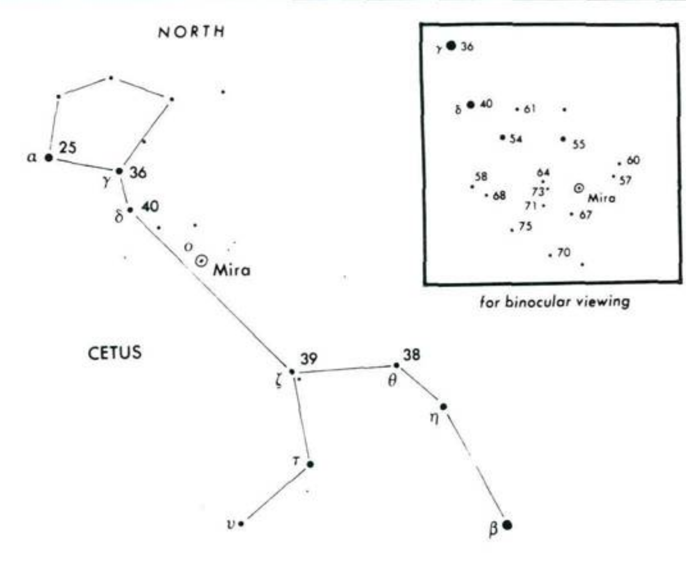
Gamma's unorthodox behavior resembles that of a star explosively blowing off its atmosphere's outer shell — a process observed in novae. Unlike the rapid and drastic changes in other types of variables, Gamma is an unexciting star to watch. But Gamma is so unpredictable that you should keep it on your list of suspicious characters. Neighboring stars Beta and Delta are good for comparing magnitudes — but don't use Alpha which is thought to be slightly variable.

R Leonis

Having a period of about 310 days, R Leonis ranks as another long-period variable. At its brightest, R Leonis only reaches 5.0 — sinking to 11.0 at minimum. Be careful not to confuse R with a nearby 5.8 magnitude comparison star. On a clear moonless night you can detect the comparison star, but avoid recording an estimate unless you see both stars clearly.

Readers having access to small telescopes can follow R through its entire cycle. The diagram on this page shows north at the top — which is correct for the naked eye, binoculars and terrestrial telescopes. Astronomical telescopes, however, reverse all these directions. If you own one, turn the page around so that north is at the bottom. At night hold the chart against the sky of Leo with the north pointed away from Polaris. This orientation will be correct for reversing telescopes.

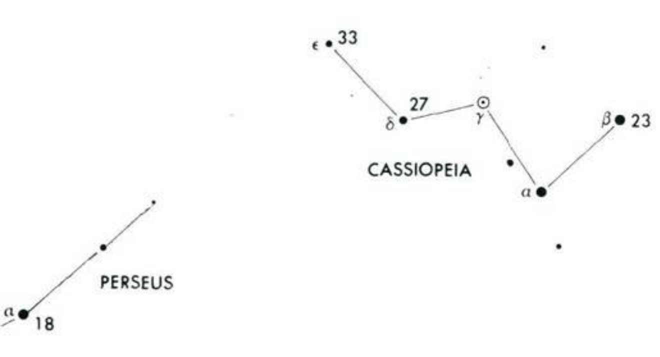
Observing variable stars is a branch of astronomical research particularly well-suited to the amateur stargazer. It requires no special instruments or formal training — just your skill at playing a detective hunt with some of the galaxy's most temperamental stars. ◆



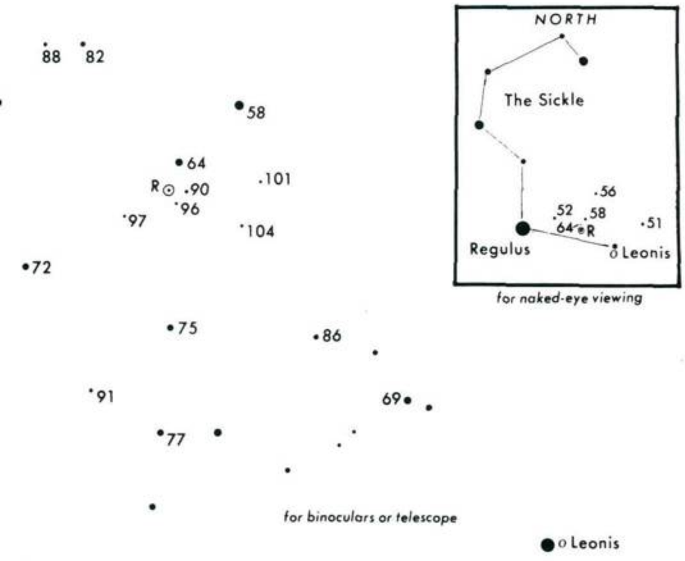
for binocular viewing

for naked-eye viewing

Omicron (ο) Ceti, better known as Mira, is a long period variable that has been as bright as magnitude 2.5. Usually it cycles from third to ninth magnitudes and back over a period of 330 days.



Gamma (γ) Cassiopeiae changed brightness erratically a few decades ago but seems to have settled down at magnitude 2.5.



for naked-eye viewing

for binoculars or telescope

R Leonis is generally not visible to the unaided eye. Its period (from one maximum to another) is about 310 days during which its magnitude varies from 5 to 11.

Leslie C. Peltier was once described by Harlow Shapley as "the world's greatest nonprofessional astronomer". Now 74 years old, he recalls viewing Halley's comet in 1910. Much of his leisure time since then has been spent observing the night sky. Among his many achievements are the discoveries of several comets and novae. For a review of the book from which this article is excerpted, see page 18.

Venus & Jupiter Trade Places

The shortest month of the year offers some celestial surprises that are worth making the effort to see. The most easily observed of these is the extremely close approach of Venus and Jupiter — a configuration called a conjunction where the two planets appear to us to be beside each other but in reality are millions of miles apart. The second treat, although it may be somewhat of an anticlimax to Eros' encounter with Kappa Geminorum, will be the asteroid's brush with Procyon on Feb. 9. Saturn remains in prime observing position to make February a better than average month for interesting sky phenomena.

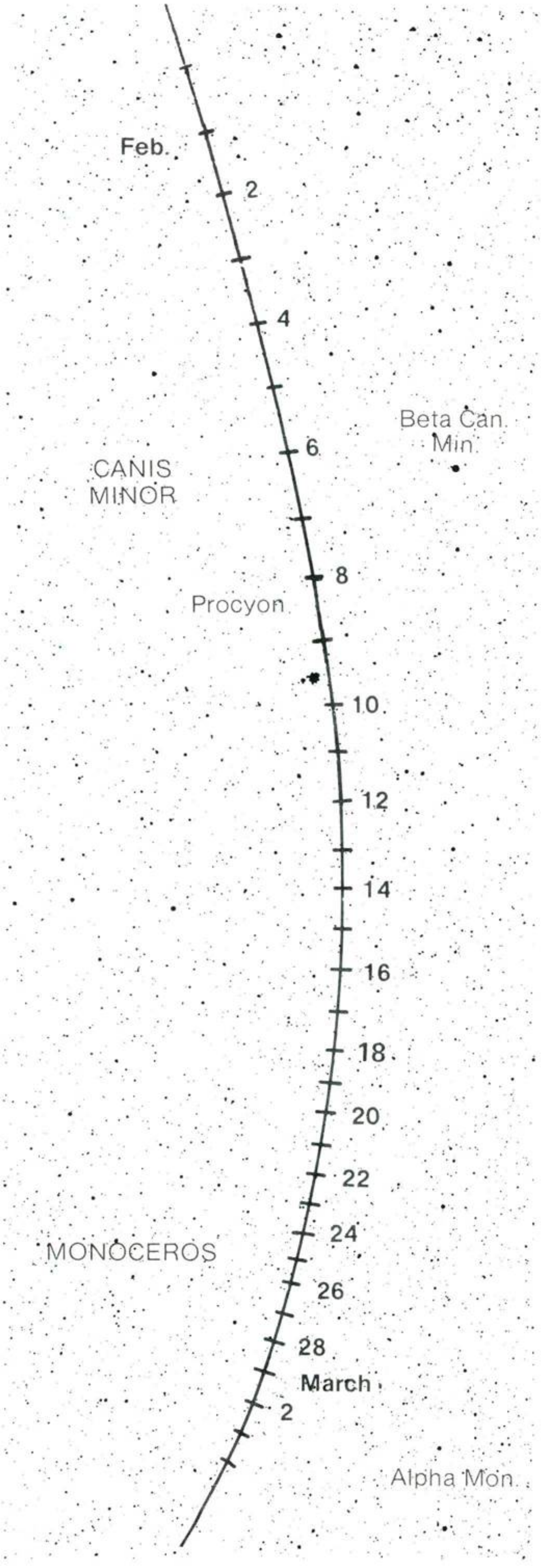
Two objects well placed for winter observation are the Andromeda galaxy (above) and the galactic cluster M-35. As our nearest spiral galaxy, the Andromeda system (also known as M-31) is a favorite target for both visual observers and astrophotographers. It is easily visible to the unaided eye on a dark moonless night. At two million light-years away, M-31 is the most distant object visible to the naked eye. Within our own galaxy only 2,600 light-years distant is M-35, a swarm of several thousand stars. The brightest hundred or so stars in the cluster give it a jewel box appearance. M-35 is about 30 minutes of arc in diameter while its dim companion — NGC-2158 — is only four minutes across. This apparently smaller cluster is actually a huge assemblage of stars six times more distant than M-35. NGC-2158 may be a rare class of cluster intermediate in size between globular clusters and galactic clusters like M-35. (See map on page 70 for M-35's location.) Both of these photos were taken on Kodak 103aF film through a five inch f/5.3 Newtonian reflector. Exposure was 45 minutes for Andromeda and 30 minutes for M-35.

Photographs by Robert Provin

Venus-Jupiter Conjunction

The main event of the month is the apparent sideswiping of Jupiter by Venus on the evening of Monday, Feb. 17. On that date, low in the southwest just after sunset, Venus will appear so close to Jupiter that they will both fit in the same low power telescopic field. To the unaided eye or binoculars the two will make a dazzling double star.

These two brilliant orbs are similar in stellar appearance to the naked eye but vastly different in the telescope. The white clouds of Venus are brilliant reflectors of the nearby sun's radiation while the more distant Jupiter, with decidedly yellowish clouds on its banded face, seems somewhat pale by comparison. The rare chance to get them both in your telescope's field of view will clearly demonstrate the differences. It will be a difficult but rewarding subject to attempt to photograph through the telescope.



This extreme close approach on the 17th is part of a dance that Venus and Jupiter will be conducting throughout February in the early evening southwestern sky. Earlier in the month, Venus will be below and to the right of Jupiter. Night after night it will gradually catch up to the big planet as they both appear to be making their way eastward among the background stars (a fact that you will probably not

OBSERVING SATURN'S SATELLITES

Date	Time (EST)	Satellite	E or W
Feb. 2	11:45 p.m.	Dione	E
3	1:30 a.m.	Rhea	E
5	6:30 a.m.	Tethys	E
5	5:30 p.m.	Dione	E
6	10:45 p.m.	Titan	W
7	3:45 a.m.	Tethys	E
7	6:45 p.m.	Rhea	E
9	1:00 a.m.	Tethys	E
10	10:30 p.m.	Tethys	E
11	4:45 a.m.	Dione	E
12	7:15 a.m.	Rhea	E
12	5:45 p.m.	Iapetus	W
12	7:45 p.m.	Tethys	E
13	10:30 p.m.	Dione	E
14	5:00 p.m.	Tethys	E
15	3:30 a.m.	Titan	E
16	7:30 p.m.	Rhea	E
21	8:00 a.m.	Rhea	E
22	3:30 a.m.	Dione	E
22	6:15 a.m.	Tethys	E
22	8:45 p.m.	Titan	W
24	3:30 a.m.	Tethys	E
24	9:15 p.m.	Dione	E
25	8:15 p.m.	Rhea	E
26	12:45 a.m.	Tethys	E
27	10:15 p.m.	Tethys	E

This table provides all the necessary information for identification of Saturn's satellites Titan, Rhea, Tethys, Dione and Iapetus. E or W refer to extreme east or west points of the satellites' orbits. For Tethys and Dione, only eastern elongations occurring during darkness in the United States are included.

This chart showing the path of the asteroid Eros through Gemini and Canis Minor is a continuation of the map in last month's Sky Almanac. Dates on the path indicate Eros' position at 7:00 p.m. EST. A 15 mile wide oblong "flying mountain", Eros will vary in brightness by nearly 1-1/2 magnitudes as it rotates. Maximum magnitude on Feb. 1 is 8.3, dropping to 9.2 by the 20th.

← Photograph by Leo C. Henzl Jr.

The crescent moon, Mercury and Spica illuminate this early morning view over Casco Bay as seen from Portland, Maine on Nov. 10, 1974. Mercury, slightly brighter than Spica, is the lowest of the three objects. The visibility of the moon's night side is due to illumination from sunlight reflected off Earth. A 28mm lens was used on a Nikkormat camera. Exposure on the Kodachrome 64 film was 16 seconds. To plan ahead for photo compositions like this the dates when the moon is near a planet or a bright star can be determined from the map on pages 76 and 77 →

Photograph by Russell E. Campbell

notice because of the faintness of the surrounding stars in the zodiacal constellations Aquarius and Pisces).

The true conjunction actually occurs when the planets appear closest together — and that will be at 2:00 p.m. EST on the 17th. But they will be near their minimum separation just after sunset on that day. For the last half of February after conjunction, Jupiter will sink into the sunset while Venus becomes more and more prominent as it slowly emerges from the sun's glare and begins to dominate the entire western sky for the next several months.

The crescent moon will be near the two planets on the 13th making a fine composition for photography without a telescope. Some examples of photographs of the conjunction or the moon-Venus-Jupiter configuration will be printed in future issues of ASTRONOMY. Both color and black and white photos are acceptable if you wish to submit your efforts. (Photos should be sent to the attention of the editors.)

Venus

It's been over a year since we've seen Venus in the evening skies and we're in for a six month span of evening Venus observing as our sister planet (Venus is next in toward the sun from Earth) catches up to us and eventually passes nearly between us and the sun next August. Between now and then Venus will seem to grow in size — when viewed telescopically — as it nears us.

During February it expands from a 10.8 second, 94 percent illuminated, nearly full sphere to an 11.7 second, 8 9 percent illuminated disk. What we're seeing is Venus slowly approaching and turning its night side toward us. It will be most impressive if you begin watching now and follow the brightest planet as telescopically it transforms from the small brilliant disk that we see this month to a gorgeous crescent by early summer. The changes are slow at this point in the Venus phase sequence.

As Venus' distance from Earth decreases from 144 million miles to 134 million miles during February, its magnitude remains the same at -3.4 — far brighter than anything else in the sky except the sun and the moon. As mentioned above in the conjunction section, Venus can be seen all month in the southwest near Jupiter just as soon as it gets dark enough to recognize it.

Jupiter

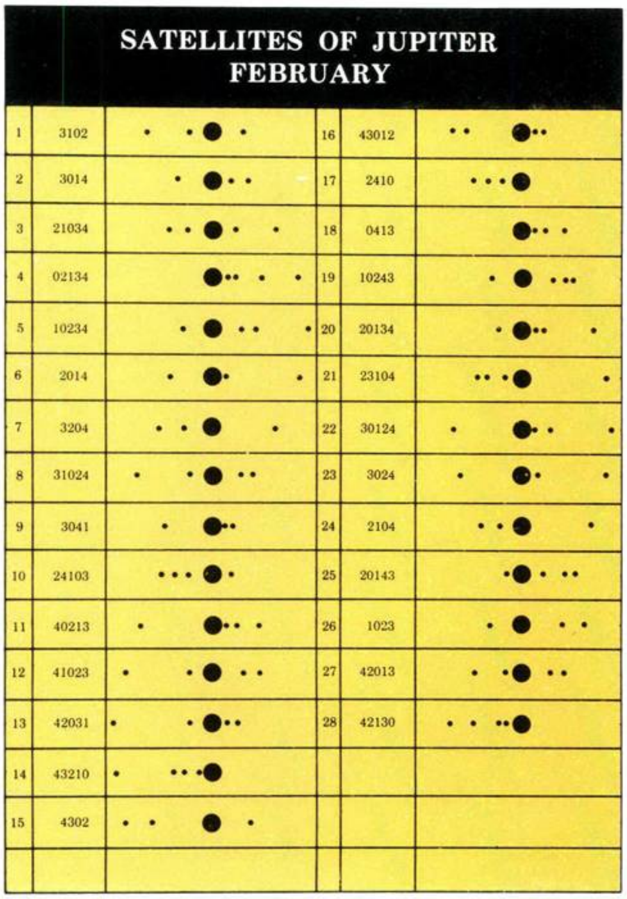
Now nearing the end of its season of observability, the giant planet is 531 million miles from Earth as the month begins. As we continue to pull away from the planet, the distance is increased to 550 million miles by the end of February. During its period of closest approach last September, Jupiter was only

2/3 the distance that it will be by the end of this month; thus the planet appears much smaller than it was at that time. Specifically, Jupiter is 34.5 seconds of arc in equatorial diameter at the beginning of the month shrinking to 33.4 seconds by month's end.

Jupiter's brightness is still significant — magnitude -1.7 early in the month, fading to -1.6 later on. Look for the big planet near Venus all month as described above. By late February and early March, Jupiter will be quite low in the southwest at sunset and although not especially difficult to find with the unaided eye, it ceases to be an object of telescopic interest for the latter part of February and March.

Saturn

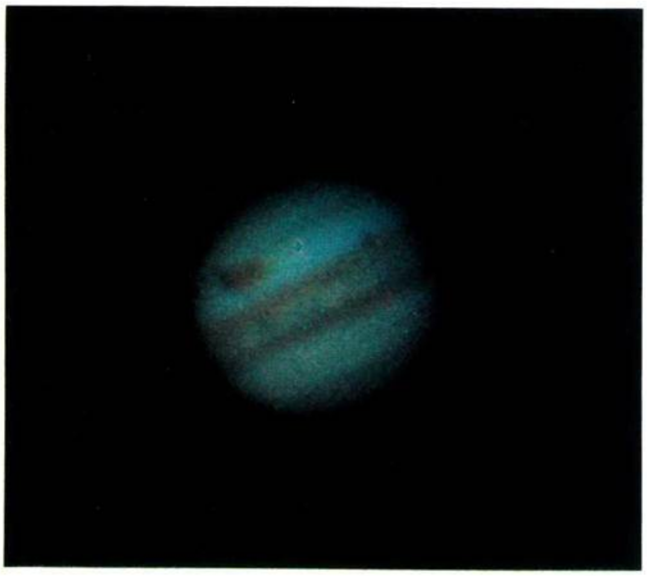
Making a picturesque triangle with Castor and Pollux in Gemini, Saturn is easily identified. At magnitude -0.1 early in the month and fading slightly to +0.1 later on, the ringed planet remains in excellent observing position for telescope users. The rings appear 46.0 seconds of arc in width on the 1st, decreasing to 44.4 seconds by the 28th. The rings form that ever fascinating oval around the 20 second wide planet itself.



SATELLITES OF JUPITER
FEBRUARY

1	3102	16	43012
2	3014	17	2410
3	21034	18	0413
4	02134	19	10243
5	10234	20	20134
6	2014	21	23104
7	3204	22	30124
8	31024	23	3024
9	3041	24	2104
10	24103	25	20143
11	40213	26	1023
12	41023	27	42013
13	42031	28	42130
14	43210		
15	4302		

The four major satellites of Jupiter orbit the giant planet in periods ranging from just under 2 days to 17 days. They can be seen to change position from night to night. Sometimes their motions become evident after only a few minutes' observation. Only a small telescope is required to detect all four of the satellites and several can frequently be seen in rigidly held binoculars. This table shows the approximate positions of the moons at about 7 p.m. (EST) on the evenings indicated. First column on the left shows the date. Second column of numbers identifies the moons and their positions relative to Jupiter's disk. (1 = Io; 2 = Europa; 3 = Ganymede; 4 = Callisto, and 0 = Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions. The orientation of the satellites is shown inverted as seen in a standard astronomical telescope.



Photograph by Martin Anderson

Shadows of two Jovian satellites are captured gliding across Jupiter's cloud tops in a rare double traverse on the night of Nov. 13-14, 1974. Eclipsing the edge of the Great Red Spot is Ganymede's shadow — nearing completion of its four hour crossing — as Europa's smaller figure creeps toward the disk's center. (For a detailed description of this event see the November 1974 issue.) The three second exposure was taken on Kodachrome II through an eight inch Schmidt-Cassegrain reflector using a 14mm movie lens for projection.

Earth and Saturn are now moving away from each other — the distance this month increasing from 758 million to 788 million miles. The ringed planet's family of satellites adds to the challenge of observing this distant world. Although a two inch scope will show the rings, more and more subtle detail is revealed as the size and quality of the telescope increases. The same is true of the satellites — with larger telescopes and clear and steady atmospheric conditions, more moons can be identified. To help in this identification a table of Saturn's satellites is included again this month. Let us know which moons you can identify in your telescope.

Mars

Mars is a "morning star" visible very low in the southeast before sunrise. However its distance of nearly 200 million miles gives it a telescopic diameter of only 4.5 seconds of arc and a magnitude of +1.5. Thus it is of little interest to astronomy enthusiasts this month.

Mercury, Uranus, Neptune, Pluto

These worlds are not conveniently visible during the evening hours. Mercury particularly is not available for observation for the entire month.

This month the Planet Finder appears on pages 76 and 77.

ASTRO-NEWS

Latest News From the World of Astronomy

Message Beamed to M-13

In a three minute explosion of radio energy, 10 million times more intense than that emitted by the sun, mankind recently yelled its first interstellar "hello". Five hours twenty minutes after being beamed from the world's largest radio telescope — the 1,000 foot wide dish at Arecibo, Puerto Rico — the signal hurled past Pluto's orbit and onward to a distant rendezvous with the globular star cluster M-13, 24,000 light-years away.

To human ears, the historic message sounds like a two-toned version of the Morse code — no more informative than listening to someone dial a push-button telephone. But alien civilizations clever enough to decode the greeting will be rewarded with a valuable resume about the human race.

What do you say to alien intellects, to minds spawned in environments probably completely different from our own? How do you say it? Any Earth languages are automatically out. Instead, the staff at the National Astronomy and Ionesphere Center at Arecibo wrote the message relying on mathematics and simple pictorial information. Math seems an especially universal language — two plus two should equal four anywhere in the cosmos.

The Arecibo communication is coded in 1,679 binary numbers — the simplest math system imaginable. Rather than using powers of 10 like our familiar decimal system, binary numbers are written in powers of 2 — thus needing only two symbols such as dots and dashes or 0s and 1s. Any technological culture intercepting the signal should recognize that the number 1,679 is the product of two prime numbers (numbers divisible only by themselves and one): 23 and 73. Hopefully they'll next try reconstructing a picture from the data by building a grid 23 characters wide by 73 characters long.

At first glance the reconstituted picture looks more like an abstract tile mosaic than a communication from intelligent beings. The message begins with a simple lesson describing the binary system used throughout the rest of the image. Across the top appear the numbers 1 to 10 written in binary notation.

The following picture sequence describes fundamental Earth biology. Again in binary language, the next symbol down reads 1, 6, 7, 8, 15, representing the atomic numbers (number of protons in an element's nucleus) of hydrogen, carbon, nitrogen, oxygen, and phosphorus — the basic chemical building blocks of life on this planet.

Message *continued on page 64*

3.8 Billion Year Old Earth Rocks Found

Rocks calculated to be 3.8 billion years old — as ancient as the oldest ever found on Earth — have been identified by two geologists in a quiet, scenic river valley in southwestern Minnesota. The rocks equal the age of others found in 1969 in western Greenland by Oxford University scientists. Material from the two sites is 300 million years older than any other previously known terrestrial rocks.

Discovery of these ancient rocks extends the preserved record of geologic history further into the little-known early years of Earth, closer to the time when the oceans and atmosphere formed and when the first primitive life may have developed. The rocks also extend Earth's record back to a point where it overlaps the moon's history as recorded in the samples returned by astronauts in the Apollo program. The lunar rocks are between 3.3 billion and 4.0 billion years old.

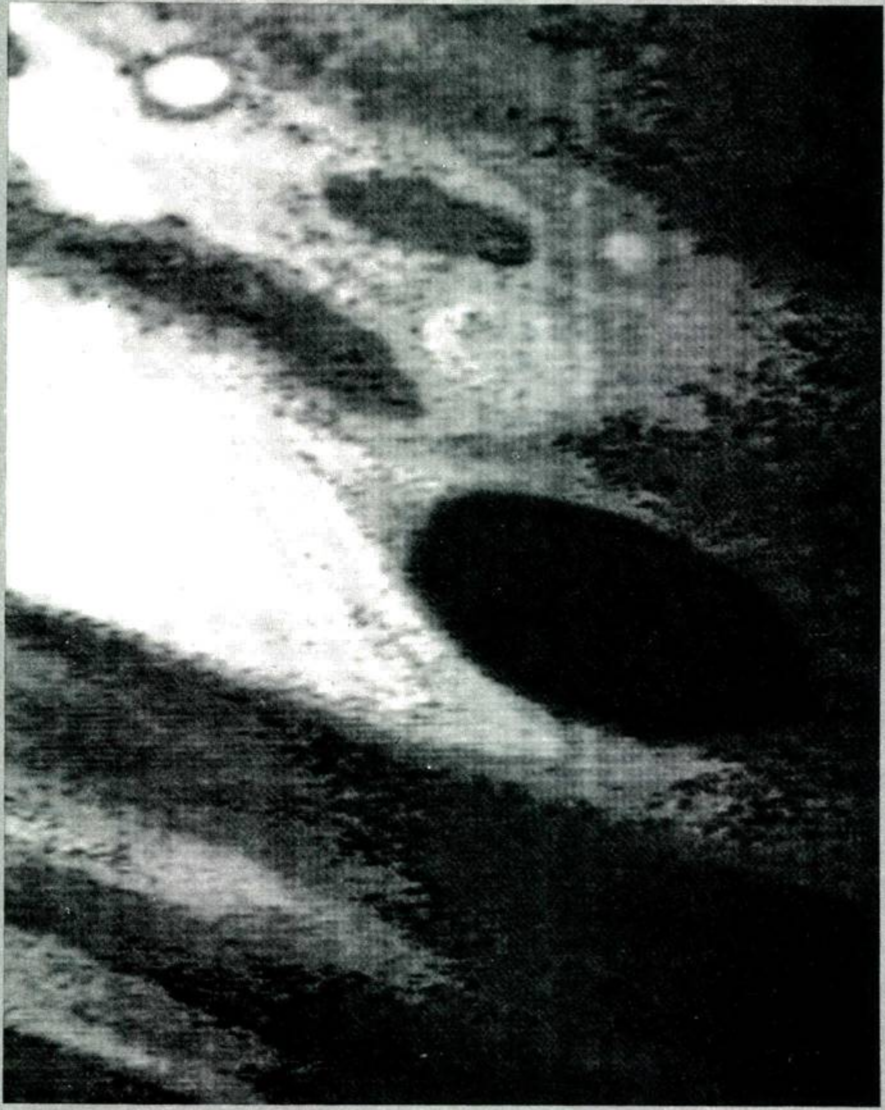
Direct comparison of moon and Earth rocks so far has revealed that our satellite probably did not form from part of Earth. High aluminum and titanium content in moon rocks, and a general dissimilarity from terrestrial rocks, suggest that the moon may have been a separate planet that was captured by Earth's gravity early in our planet's history.

Scientists believe that Earth was formed about 4.5 billion years ago, but rocks older than 3.0 billion years have rarely survived because Earth continually recycles its rocks through volcanism and mountain building.

On the airless and geologically dead moon few changes occur. The astronauts' bootprints, for example, will be there for our descendants to examine 10,000 years from now. The moon is today essentially as it was 3.5 billion years ago when it recovered from a billion year era of internal activity and surface meteoric bombardment.

In Greenland, the 3.8 billion year old rocks occur in a small patch of land between the Greenland Ice Cap and the sea. The Minnesota rocks are found only in a narrow band along the Minnesota River, where they were exposed during the last Ice Age by a huge river that scoured out the wide valley. The rocks of both regions were formed during periods of major convulsions and mountain building activity on Earth. No special significance is attached to the fact that rocks of the same age were found in such widely separated regions.

Jupiter's Polar Region Scanned



NASA Photograph

From 1.3 million miles above Jupiter's north pole, Pioneer 11 viewed the planet's cloud belts from a vantage point never before achieved. The Great Red Spot just peeks around the limb indicating we are seeing some of Jupiter's southern hemisphere. The north polar region appears dull and featureless but other photos show indications of a "bubbling porridge" appearance reminiscent of the solar surface.

The interplanetary voyager Pioneer 11 successfully looped around Jupiter on Dec. 2, 1974 giving man his first glimpse of the Jovian polar regions. The spacecraft survived the lethal radiation belts that girdle the big planet and is now heading for a 1979 rendezvous with Saturn.

Although some spurious commands affected some scientific instruments during the flyby, there was none of the radiation damage experienced by Pioneer 10 last year. When controllers commanded the instruments back to their correct positions, Pioneer 11 seemed to be working just as well after encounter as it did before. It continued to transmit excellent pictures of the planet.

The imaging photopolarimetry experiment produced good images of satellites, of the north and south poles of Jupiter, and of the characterisitic Jovian zones, belts, and spots. The great plume is still very much in evidence, but shows changes in its rising air mass head since Dec. 1973 (see photo, page 27). The Great Red Spot possesses a slightly different tail structure and close to it is a large white oval which has caught up with the Red Spot and disrupted nearby dark areas — breaking up this part of the Red Spot (this page). The Little Red Spot of last year has disappeared.

The Jovian polar regions seem to be devoid of cloud structure; the color photos show a bluish polar haze. The photometry and photopolarimetry indicate that both polar regions are covered with aerosols (liquid particles in atmospheric suspension) rather than the clouds of lower latitude regions, and these aerosols are at lower levels than elsewhere on the planet.

The celestial mechanics results confirm Pioneer 10's finding that Jupiter is essentially a fluid body under hydrostatic equilibrium with no detectable gravitational anomalies.

Pioneer 10 detected an increase in meteoroids in the vicinity of Jupiter. The question was whether these represented infalling debris attracted by Jupiter's immense gravity or particles in orbit about the planet. Pioneer 11 followed an orbit that allowed experimenters to differentiate between these two possibilities because of the orientation of the meteoroid detection panels to the line of flight, and their being shielded by the dish antenna. Five penetrations were recorded during the flyby. One was known to be spurious; two are in doubt. The remaining two took place on the inward leg of the trajectory. No particles were detected on the outward leg of the trajectory when the detection cells were screened from the line of flight by the antenna dish. These findings suggest that the particles result from infalling meteoroids rather than orbiting bodies.

Taken with the observations made through the asteroid belt, it appears that the meteoroids in the solar system result from comets and not from the asteroid belt. Pioneer 10 has shown that the hit rates from meteoroids is about the same within and outside of Jupiter's orbit. Within the orbit of Jupiter the only major anomaly to a fairly constant hit rate was observed by both Pioneers as being at the distance of Mars' orbit where the solar system is mysteriously swept relatively clean of cometary debris.

Following its encounter with Jupiter, Pioneer 11 is now heading high above and across the solar system toward a 1979 rendezvous with Saturn. Preliminary targeting is for the spacecraft to fly between the planet and the rings, and then behind the planet itself — with a flyby observation of Titan before Pioneer heads out from the solar system in exactly the opposite direction from Pioneer 10. Encounter with Saturn is planned for Sept. 2 or 3, 1979. At that time Saturn will appear just six or seven degrees from the sun.

New Measurements Made of Jovian Radiation Belts

Pioneer 11's successful flight to within 27,000 miles of Jupiter on Dec. 2, 1974 produced new measurements of the giant planet's radiation belts. Electrons with energies greater than three million electron volts were found by Pioneer 11 to be present in the inner Jovian radiation belts at fluxes 10 times that expected from the radio observations made from Earth. It may be that the synchrotron radiation theory that astronomers used for their estimates is basically at fault and needs updating. Alternatively, the high flux may result from some as yet not understood unique property of the Jovian environment. But at Jupiter, the Pioneer 11 results appear to show that many more electrons are involved in producing the radio emissions than radio astronomers thought. And this means that additional sources of energy are required to accelerate these electrons.

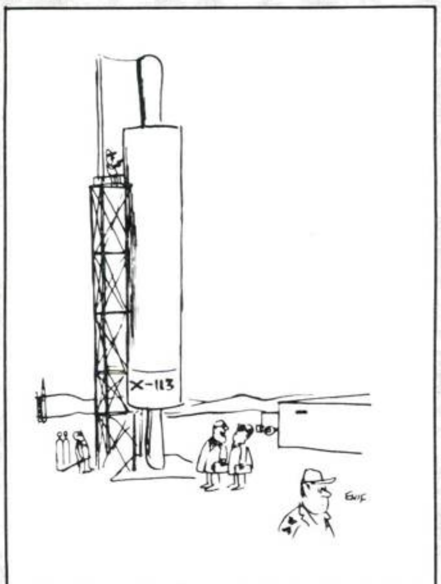
Since many interpretations of astrophysical environments such as that of the Crab nebula have been made on the basis of radio observations converted to electron fluxes by the conventional synchrotron radiation theory, the Pioneer 11 discovery may call for a complete reappraisal of many accepted theories about conditions and energies in celestial radio objects.

A new concept of the Jovian magnetosphere and its environment emerges from the preliminary Pioneer 11 results. Since Pioneer 11 traversed the Jovian environment over a wider range of latitudes than its predecessor, the essentially flat magnetosphere model deduced from Pioneer 10 data is found no longer valid. A simple extrapolation of Pioneer 10 results to high latitudes gives much less flux of energetic particles than are measured by Pioneer 11. Additionally, Pioneer 11 found that the peak values of electron and proton fluxes are not exactly on the magnetic equator but on either side of it, and that the north and south flux peaks are not identical. The Jovian magnetosphere appears to have a large pulsating shape, blunt-nosed toward the sun.

There is strong evidence now that all the Galilean satellites sweep energetic particles from the Jovian environment. At one time it was also postulated that Io was connected to the planet by a "flux tube" along which intense currents of electricity discharged and produced the modulation effects on the radio waves emitted by Jupiter, as recorded by Earth based radio astronomers. Pioneer 11 crossed a region of space where the hypothetical flux tube had been located only four minutes beforehand. It was expected that the magnetometer aboard the spacecraft would detect the magnetic field remaining from the current flow between satellite and planet. No such effect was observed.

Ultraviolet observations of the satellites and space around them confirmed the hydrogen halo, or torus, of Io as originally detected by Pioneer 10. But none of the other Galilean satellites have a similar torus to Io. The big question is now why Io should be unique in producing a hydrogen torus from the protons which it captures. This may be tied in with the sodium halo of Io and the peculiar surface which is now believed to be salt encrusted similar to a dry lake bed (see companion article).

Io's hydrogen torus is believed to originate from the protons swept by the satellite from the radiation belts. These protons capture electrons at the surface of the planet and then acquire sufficient kinetic energy as atomic hydrogen to escape from the gravity field of Io. However, they do not have sufficient thermal energy to escape Jupiter's gravity field so they spread along the orbit of the satellite. With time, the atoms again become ionized and merge into the plasma surrounding the planet. But there is no satisfactory explanation of why the other large satellites which also sweep protons from the radiation belts do not each have a torus similar to that of Io.



"I GOT THE IDEA FROM MY WIFE."

Scientists Link Lunar Gravity to Earth Life

Orbiting Earth at only 1/3 of today's distance, the moon skirts frighteningly close to the boundary where our planet's gravity shatters celestial intruders. From its dangerous perch the moon's own gravity unleashes catastrophic global events. Energy generated by monstrous tides bakes Earth's surface until the oceans threaten to boil away.

This is no scenario for doomsday, but a description of conditions on Earth three billion years ago according to three Cornell University scientists. From piecing together fossil and geologic evidence, D. L. Turcotte, J. C. Nordmann and J. L. Cisne believe that during Earth's stormy youth the moon's closer orbit may have been a catalyst for bringing about life on our world.

Scalding oceans under the moon's gravitational muscle hardly sound like an inviting place for life to survive — much less get started. However laboratory experiments duplicating such hellish conditions give promising results. Boiling and cooling an organic "soup" of complex molecules forms structures looking remarkably like cells. A similar "broth" probably filled Earth's early oceans.

There is intriguing evidence that the earliest known record of life — algae fossils — roughly coincides with the time of the implied thermal trauma. The scientists think this blue-green algae — dating back three billion years — likely felt right at home in steamy oceans.

Recent geologic findings also tell of hot times on Earth during the moon's tight orbit era. Rocks from 2.8 billion years ago show that molten material flowed into the cracks and fissures of older overlying rocks. The Cornell team sees it as the work of an intensive global heat wave from tidal activity.

Studying coral and algae fossils also gave the tipoff that Earth and the moon were once closer companions in space. Since coral and algae growth patterns are linked to the solar day, a primordial calendar can be decoded from their fossils. The calendar reads 420 days for the year three billion B. C. (instead of the 365 days per

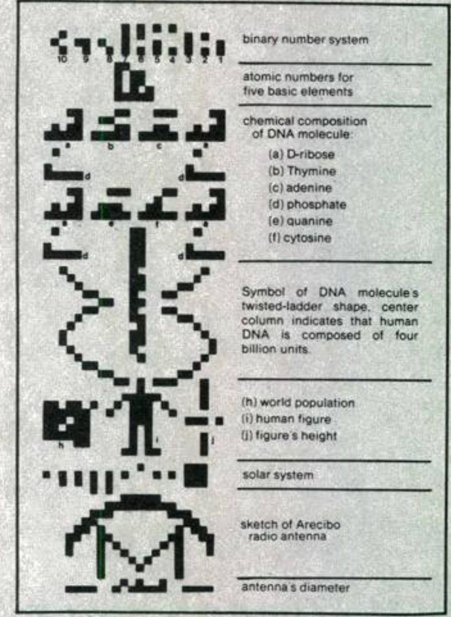
Gravity *continued on page 65*

Message

continued from page 61

Using these five abundant elements, the following two rows give the chemical formula for deoxyribonucleic acid (DNA), a complex macromolecule. DNA acts as a tiny organic computer by containing all the genetic information necessary for controlling the form, living processes and behavior of every type of life on Earth — from man to microbe. The message's designers graphically show part of DNA's spiral structure, resembling a twisted ladder. Between the double helix a binary number stacked vertically reads a whopping four billion to indicate the fantastic amount of information each DNA molecule can chemically store and transmit to future generations. From this statistic, alien biologists should get some grasp of the rich tapestry of life forms made possible on the planet Earth through DNA's magic.

The tail of each helix points to a human figure bracketed by the number four billion (approximating Earth's present population) and the number 14, suggesting that the human's real height is 14 times the signal's 12.6 centimeter wavelength (used as the message's basic unit of measurement). Below the human, Earth stands out as his home world in a solar system schematic giving a very rough idea of the planets' relative sizes.


10 9 8 7 6 5 4 3 2 1
binary number system
atomic numbers for five basic elements
a b c
d d
e f
chemical composition of DNA molecule:
(a) D-ribose
(b) Thymine
(c) adenine
(d) phosphate
(e) quanine
(f) cytosine
Symbol of DNA molecule's twisted-ladder shape. center column indicates that human DNA is composed of four billion units.
h i j
(h) world population
(i) human figure
(j) figure's height
solar system
sketch of Arecibo radio antenna
antenna's diameter

When properly reconstructed, man's first radio message to alien civilizations appears as a mosaic — symbolically and mathematically describing life on Earth. See article for diagram's full explanation.

Attention Readers

ASTRONOMY's index to Volume II, 1974, will be available next month. Watch for our ad in the March issue.

Looking like a science fiction monster, a sketch of the Arecibo antenna hanging upside down (pointing away from Earth) dominates the bottom of the message. The last binary number — reading 2,430 — tells the antenna's diameter (1,000 feet) by using the broadcast wavelength again.

The intergalactic greeting was beamed starward to inaugurate the new resurfacing of the Arecibo radio telescope — the largest and most powerful such instrument in the world. The dish's 2,000-fold increase in sensitivity promises to open a new era in radio astronomy.

Ever since Project Ozma in the early 1960s first used a radio telescope to listen to nearby stars for intelligent signals, Frank Drake, director of the observatory and other stronomers have toyed with the idea of transmitting messages as well as receiving them. But only Arecibo's godlike new powers have finally provided the potential for transmitting a signal of any reasonable strength.

The Arecibo message does not represent the first attempt by man to make his presence know to alien civilizations. An etched aluminum "postcard" now zooming out of the solar system aboard the Pioneer 10 Jupiter probe will pictorially tell any alien finding it about the nature and location of our solar system and our physical appearance. Saturn-bound Pioneer 11 carries an identical artifact.

But as these two space age notes-in-bottles blindly drift through space, Arecibo's greeting is flashing toward a very special and promising target — the globular star cluster M-13. Lazily orbiting above the plane of our Milky Way galaxy, this small island of 300,000 closely packed stars matches the diameter that the radio beam will have diverged to when reaching the cluster's distance of 24,000 light-years. None of the beam's energy will be wasted as it instantaneously zaps more than a quarter-million stars and potential solar systems.

Is anyone living there to hear man's electromagnetic shout? "I would say there is about a one in two chance of there being a civilization in M-13," speculates Cornell astronomer Carl Sagan. Hopefully at least one technological society can devote time and resources to constantly monitor its Milky Way neighbor for signs of such an astrogram. At that distance, a society would need a radio telescope nearly a twin in size and sensitivity to Arecibo monster. If M-13's inhabitants miss the three minute encounter, they might catch the reruns since plans call for automatically repeating the message whenever the huge antenna is not being used for research.

At this moment, the 30 million mile long bundle of energy continues whizzing through the galaxy — but traveling even at the speed of light, the signal will not reach its bulls-eye until 24,000 years from now. If technological civilizations existing now, or yet to be born, pick up the beacon, mankind could not anticipate an answer before 49,974 A.D.

What kind of reply would the cluster's inhabitants send 500th century man? Frank Drake had just arrived back at Cornell University when he received a telegram from Arecibo describing a signal purportedly picked up by the giant dish. It translates: "Message received. Help is on the way. — M-13."

Rendezvous With Saturn Set for 1979

If you thought Pioneer 11's treacherous glide through Jupiter's radiation fields was spectacular — just wait! The roller coaster ride has only begun! Pioneer is destined to rendezvous with Saturn in September 1979.

Instead of bouncing the 570 pound spacecraft off Saturn's gravitational field and onto Uranus, NASA scientists have opted for plunging Pioneer within 2,300 miles of Saturn's cloud tops — a pathway carrying it inside the spectacular ring system.

As the space probe flies out near Saturn's equatorial plane and skirts below the rings, man will receive historic close-up pictures of their composition. Ground based radar studies have reported that the colorful ring system appears to contain boulder size chunks of material swimming around the giant planet at speeds approaching 90,000 m.p.h. Pioneer must be targeted to remain a safe distance inside the ring system, avoiding possibly being torn apart by drifting into this deadly snowstorm of particles.

Whizzing away from Saturn as the fastest man made object yet launched, Pioneer will next pass within 12,000 miles of Saturn's largest moon, Titan. Slightly bigger than Earth's moon, Titan seems to possess a methane atmosphere, making it a possible candidate for at least simple life forms. Because of this chance the space probe will remain at a safe enough distance to avoid crashing into Titan and possibly contaminating it with Earth organisms.

Scientists ruled out Uranus because they doubted if Pioneer's nuclear powered generators could operate all onboard experiments simultaneously by the time it reached that distant world.

OSCAR-7 Opens Space to Ham Radio Operators

Recently joining the armada of complex multimillion dollar weather, navigation, communication and military satellites lacing orbits around our globe is tiny OSCAR-7, a satellite built by and for ham radio operators.

The first OSCAR (Orbiting Satellite Carrying Amateur Radio) was launched in 1960, and transmitted only a 144 MHz pulse detectable on relatively low cost ham equipment. Weighing only 65 pounds, this latest satellite in a series of seven is packed with electronics for handling 35 conversations simultaneously and beaming 35 telemetry channels earthward.

As a communication relay station, OSCAR-7 serves radio amateurs around the world and is a new link for transmitting medical information to isolated areas, hurricane warnings, and other emergency messages. Unlike larger communication satellites OSCAR's design allows simple, portable equipment to communicate with it. OSCAR user terminals can be located in automobiles, small pleasure boats, aircraft or city apartments — and transported wherever needed in emergencies.

OSCAR-7 also continues a relatively new educational program (initiated by OSCAR-6) directly involving students nationwide in space science projects. Through NASA's cooperation with the American Radio Relay League (ARRL), inexpensive ground terminals placed in classrooms use OSCAR-7's telemetry to demonstrate science concepts ranging from the Doppler effect to orbital mechanics.

The midget communication satellite was built from thousands of dollars worth of hardware donated to the Radio Amateur Satellite Corporation (AMSAT) by numerous aerospace companies. Members of AMSAT's world group worked evenings and weekends in constructing the "home built" relay station. The result: A bargain basement tag of $60,000 for a satellite that would have cost about $2 million if NASA — with its much stricter quality control — had tackled the project.

But to make the expensive vault into space, tiny OSCAR-7 had to approach NASA as a penniless hitchhiker. NASA generously listed the satellite on a "space available" basis, like some thrifty air traveler. Finally last November, OSCAR-7 rocketed skyward as a piggyback companion to an advanced weather satellite and Spain's first satellite, INTASAT A.

Orbiting Earth at 876 miles, OSCAR-7 should last longer than its predecessors and transmit at greater power. Its beam can be received at 29.45 MHz and transmissions to the satellite occur on 145.95 MHz.

Free curriculum material for OSCAR-7 experiments using inexpensive equipment is being offered to teachers by ARRL, 225 Main St., Newington, Conn. 06111.

Gravity *continued from page 63*

year now) meaning that Earth was once spinning faster. Having the moon closer to Earth provided the mechanism needed to slow Earth down to today's spin rate.

The ironic idea of the moon's intervention in biochemistry raises important new questions about extra-terrestrial life. Must this scenario be repeated on other worlds for life to appear? If so, then life may not be as abundant in the galaxy as astronomers suspect. How many planets beyond the solar system have such relatively large satellites as our moon?

Neptune Warmer Than Thought

Neptune has been found to be warmer than it would be if it were warmed purely through solar radiation. In fact, despite being further from the sun than Uranus, Neptune is the warmer of the two planets. If Neptune were a "blackbody", or a perfect absorber of the radiation falling on it, at its distance from the sun it would be expected to have a temperature of -368 degrees Fahrenheit — whereas the temperature recently determined for Neptune is actually about -356 degrees.

This strange phenomenon is apparently not unique unto Neptune; in 1967, Jupiter was found to be warmer than it should be. While Neptune radiates twice as much heat as it absorbs, Jupiter actually radiates almost three times as much heat as it absorbs. Saturn also is warmer than it should be. In fact, of all the Jovian planets — the four giant planets — only Uranus has a temperature no higher than would be expected on the basis of its distance from the sun.

In the case of Neptune, this higher-than-expected temperature cannot be explained as solely the result of the greenhouse effect — the tendency of an atmosphere to capture and retain heat. Laurence Trafton of the University of Texas and Robert Murphy of the University of Hawaii argue that Neptune more likely has an internal heat source.

This internal heat source is no atomic furnace at the planet's core, nor is there a molten core such as Jupiter may have. Trafton and Murphy argue that the source of Neptune's heat is the tides which Triton, the larger of Neptune's two moons, causes. This is a phenomenon similar to the tides in Earth's oceans which are produced by the gravitational attraction of our moon.

A tide can be thought of as a bulge in Earth's watery envelope. There are two bulges — one on the side facing the moon and one on the opposite side as well. They stay stationary with respect to the moon, always lined up directly toward and away from our satellite. While these bulges remain stationary, the solid Earth rotates beneath them. This produces friction which in turn causes a very slight slowing of Earth's rotation, and the energy which is dissipated in this manner is converted to heat. This is, of course, what happens as the result of friction anywhere in the universe.

The slowing of Earth's rotation is very slight. The period of rotation is increasing by 1/1,000 of a second per century, and the heating of Earth through tidal friction is also very slight (it is difficult to calculate the exact magnitude of the heating of Earth through tidal friction). In the case of Neptune, tidal friction is a much greater force, both because Triton is a very large satellite — it is a little larger and more massive than our moon — and because Neptune's rotation is faster than Earth's.

This theory explains why Uranus does not show a similar heating effect. If tidal friction is the correct explanation of Neptune's temperature, the fact that Uranus has no large satellites would fit in very well with its lack of an internal heat source.

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ASTRONOMY

Index to Vol. 1

In response to requests from our readers and schools, ASTRONOMY has just published a cumulative index to Vol. 1. This subject index covers August, September, October, November and December, 1973, which includes issue Nos. 1 through 5. Index to Vol. 1 is available for $1.00 each, including handling and first class postage.

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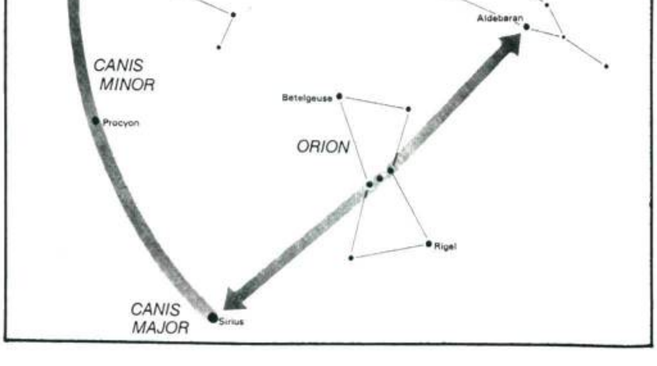
STAR DOME

FEBRUARY

Orion is the king of constellations. With two first magnitude stars and five of the second magnitude, this magnificent winter grouping is unmatched by any other stellar configuration visible to the unaided eye. Its stars are collected in an arrangement that makes Orion the most distinctive constellation of all. Especially unmistakable are the three second magnitude stars forming the belt of the mythical giant hunter. Above the belt are Betelgeuse and Bellatrix marking the hunter's shoulders. An equal distance below the belt, Rigel and Saiph form the hero's legs.

Throughout recorded history, Orion has always been visualized as a man. In looking at the star grouping this certainly is understandable for it is one of the very few constellations that does look like what it was named for. If you had a chance to name Orion again today, would you name it after something in human form?

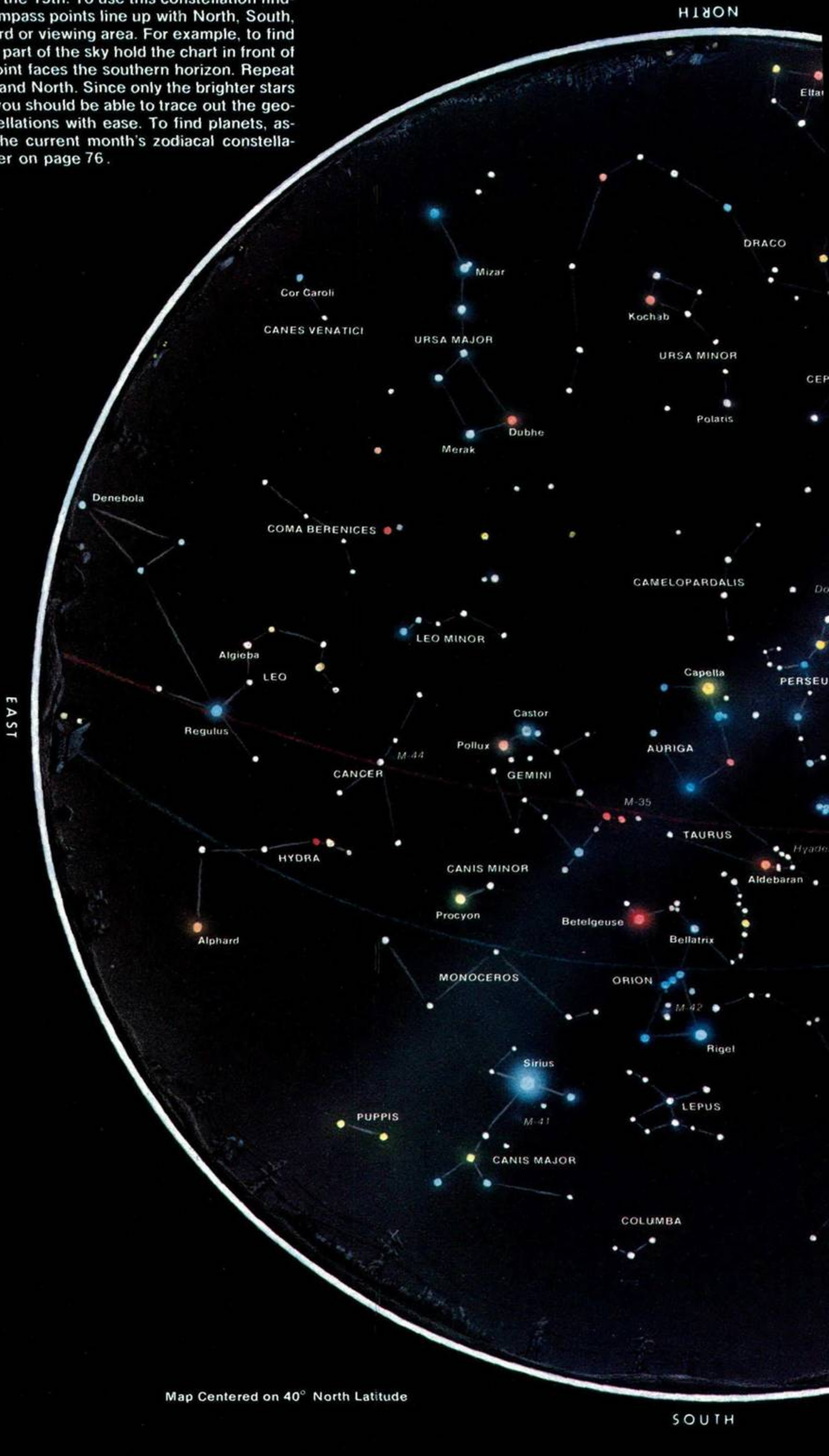


Orion is one of the few celestial figures mentioned in the Bible. The Hebrews saw the group as a "Kesil" or fool who was visualized in the sky as standing on a rabbit (the constellation Lepus) and pursuing a flock of doves — the Pleiades. However, the Babylonians (the Hebrews' neighbors) pictured Orion as their supreme god and styled him after the mighty hunter. Most other sky mythologies have adopted the hero image for Orion.

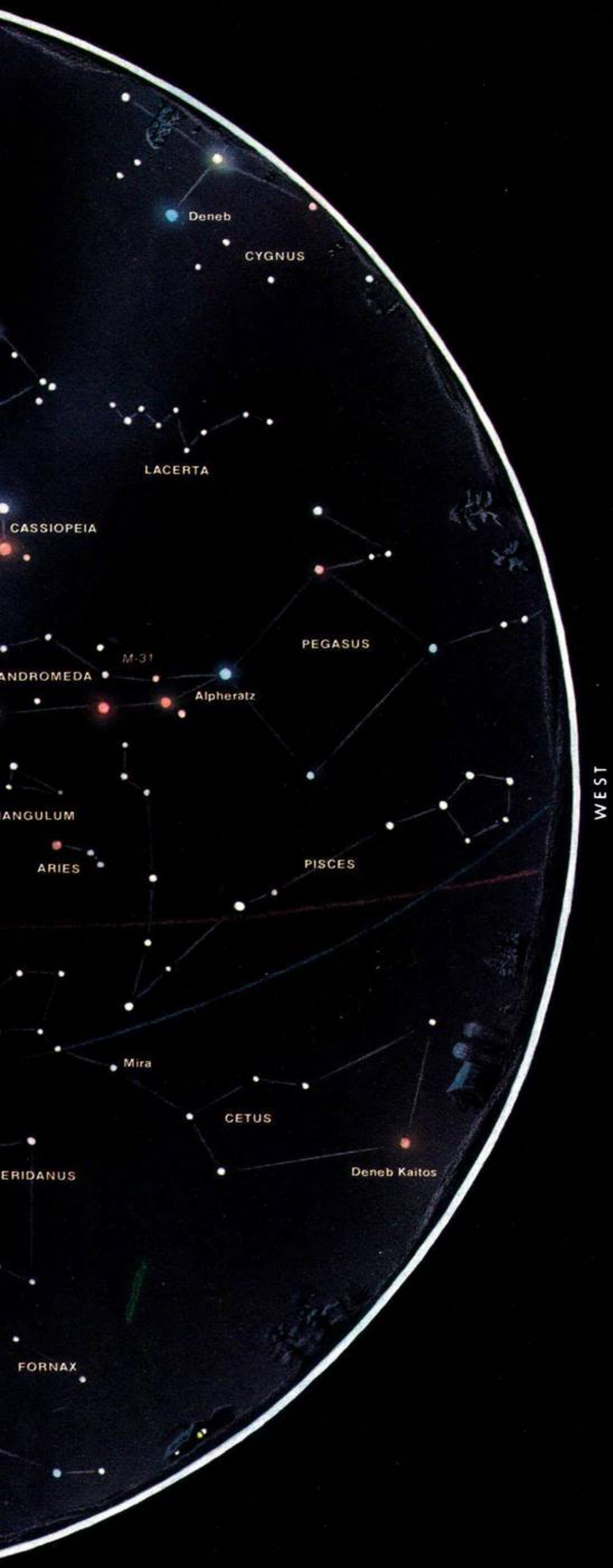
In Greek mythology, Orion was a handsome and mighty young hunter who experienced more romantic misadventures than any character from a television soap opera. After unsuccessfully courting Atlas' seven daughters, Orion's love focused on beautiful Merope, daughter of the King of Chios. To prove his affection Orion cleared the island of wild beasts — only to keep postponing marriage once it was finally offered him. Finally, when Orion was once drunk he insulted Merope, and her angry father schemed with the god Dionysus to blind Orion for punishment.

After the goddess Aurora eventually restored Orion's eyesight he lived on the island of Crete as huntsman for the goddess Artemis. But jealousy between Aurora and Artemis ultimately led to Orion's death. Some stories say that Artemis killed Orion, while other versions depict Apollo as being tricked into murder by his sister Artemis. Orion was honored after his death by being placed in the heavens as a constellation.

Star Dome approximates the sky as it appears at 8 p.m. Local Standard Time on the first day of the current month. The same constellations are visible one hour earlier on the 15th. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 76.


NORTH
Eltar
DRACO
Mizar
Cor Caroli
CANES VENATICI
Kochab
URSA MAJOR
URSA MINOR
CEP
Polaris
Dubhe
Merak
Denebola
COMA BERENICES
CAMELOPARDALIS
Do
LEO MINOR
Algieba
LEO
Capella
PERSEU
EAST
Castor
Regulus
Pollux
AURIGA
M-44
CANCER
GEMINI
M-35
TAURUS
HYDRA
Hyade
CANIS MINOR
Aldebaran
Procyon
Betelgeuse
Alphard
Bellatrix
MONOCEROS
ORION
M-42
Rigel
Sirius
LEPUS
PUPPIS
M-41
CANIS MAJOR
COLUMBA
SOUTH

Map Centered on 40° North Latitude



Map by Adolf Schaller

Off to the left of Orion's belt stands the hunter's eternal companion Canis Major, the big dog. This constellation boasts the sky's brightest star (excluding the sun) — Sirius, glistening at -1.5 magnitude. Lying only 8.6 light-years away, Sirius radiates about 27 times as much light as our sun.

Use Sirius as a starting point for touring the bright stars outlining the circumference of the winter circle. Moving clockwise, follow a gentle arc toward Procyon, a star whose brilliance is somewhat overshadowed by nearby Sirius. At magnitude + 0.4, Procyon is part of the constellation identifying Orion's other hunting dog, Canis Minor. The little dog takes top prize as easiest of all constellation figures to outline — only two stars make up the entire animal. Canis Minor might more fittingly have been called the "dog bone".

Moving farther along the arching path, we reach two stars of almost equal brightness sitting side by side. They appropriately mark the constellation Gemini the Twins — the star pair which was given the twins' names, Castor and Pollux.

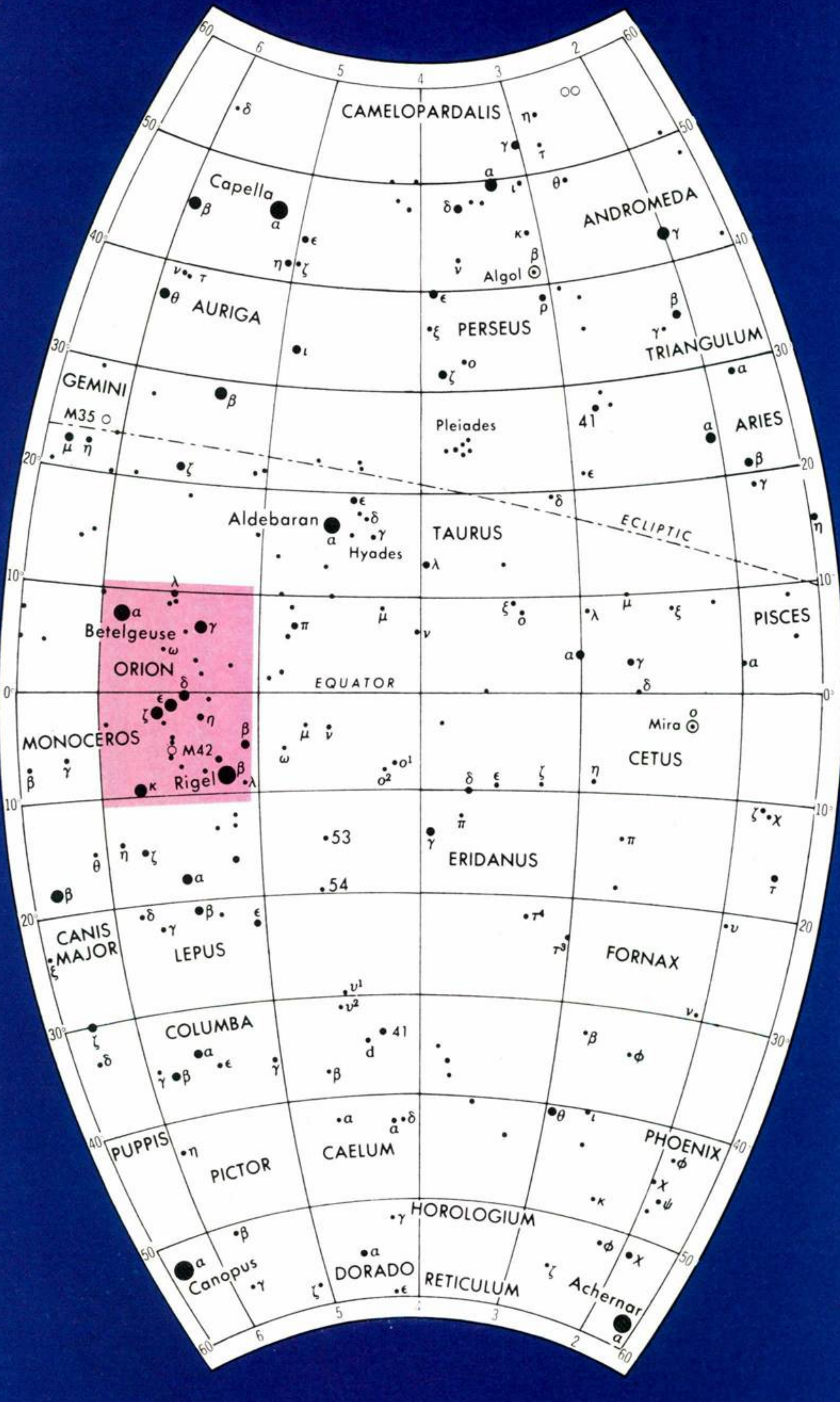
In mythology the twins were a popular pair of brothers separated only by the fact that Pollux was divine while Castor remained mortal. They were honored as the special protectors of sailors, and their constellation Gemini ranks as one of the 12 star patterns comprising the zodiac (circle of animals), the beltway marking the sun's and planets' pathway across the sky.

When observing Castor (the right star of the two), keep in mind that its shining pinpoint really represents the combined glow of six suns. Castor is an intricately arranged multiple star system of two pairs of double suns orbiting each other at roughly nine billion miles. Add to them a dim pair of red stars lazily drifting almost 100 billion miles from the system's gravitational center.

Be sure not to mistake the sparkling zero magnitude object to Pollux's right as a permanent fixture. It's actually the ringed planet Saturn slowly creeping through the winter constellations on its ponderous odyssey around the sun. For the next couple of years Saturn will be adding brilliance to the February sky and confusing things for novice star watchers.

Continuing along our path Capella's bright beacon marks the next stop. Capella lies within the constellation Auriga, shaped like a pentagram or a house with a shallow roof. Auriga is sometimes called the charioteer, while others refer to him as the goat herder. Capella's literal translation means "she goat" and the small nearby triangle of three faint stars is often referred to as the three kids.

Near the base of Auriga's pentagram dwells the winter family's most fearsome member, Taurus the bull. A V-shaped star cluster called the Hyades forms Taurus' face, while reddish supergiant Aldebaran adds dramatic emphasis as the bull's angry right eye. The V's open end points upward toward


CAMELOPARDALIS
Capella
AURIGA
GEMINI
M35
ANDROMEDA
Algol
PERSEUS
TRIANGULUM
ARIES
Pleiades
ECLIPTIC
Aldebaran
Hyades
TAURUS
PISCES
Betelgeuse
ORION
EQUATOR
MONOCEROS
M42
Rigel
Mira
CETUS
ERIDANUS
CANIS MAJOR
LEPUS
FORNAX
COLUMBA
PUPPIS
PICTOR
CAELUM
PHOENIX
HOROLOGIUM
Canopus
DORADO
RETICULUM
Achernar

Star Magnitudes

● ● ● ● ● ● • • • ·

—1 0 1 1½ 2 2½ 3 3½ 4 5

○ Cluster or Nebula

⊙ Variable Star

+ Nova

Map from **Guideposts to the Stars**; reprinted permission of MacMillan Publishing Co., ©1972 by Leslie C. Peltier.

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α	**Alpha**	η	**Eta**	ν	**Nu**	τ	**Tau**
β	**Beta**	θ	**Theta**	ξ	**Xi**	υ	**Upsilon**
γ	**Gamma**	ι	**Iota**	ο	**Omicron**	φ	**Phi**
δ	**Delta**	κ	**Kappa**	π	**Pi**	χ	**Chi**
ε	**Epsilon**	λ	**Lambda**	ρ	**Rho**	ψ	**Psi**
ζ	**Zeta**	μ	**Mu**	σ	**Sigma**	ω	**Omega**

a second and third magnitude star marking the tips of Taurus' huge horns. Actually Taurus shares the star on his left horn with the constellation tracing for Auriga giving the impression that the angry bull is poking the goat herder in the backside.

A smaller star cluster named the Pleiades explains why the bull is so mad. Located in Taurus' shoulder, the cluster symbolizes a wound inflicted from a spear thrown by Orion. The Pleiades is the name given to Atlas' seven daughters, still being pursued across the sky by Orion. Although six stars in the cluster are clearly visible, trying to pick out the seventh sister makes a good test of your eyesight. In reality hundreds of stars form the Pleiades cluster. The entire cluster is about 50 light-years in diameter and 500 light-years distant.

As revenging Taurus charges Orion, you'll notice that the hunter is not taking any chances. A bent row of stars extending up from Betelgeuse depicts Orion's outstretched arm protectively raising a club. From the star Bellatrix on his left shoulder, an arm connects to an arc of four fourth magnitude stars symbolizing a shield. Meanwhile two stars line up with the middle star of Orion's belt to trace his hunting knife. Where did Orion ever find a place to carry his spear?

Close-Up on the Orion Region

Of Orion's stars, Betelgeuse is the most famous. It has many remarkable attributes — including its name. Proper pronunciation of this star's Arabic name is BET-el-jeus, but the popular "Beetle-juice" is probably easier to remember. Let's take a closer look at this star.

Betelgeuse's size is frighteningly impressive — its diameter is close to that of Mars' orbit. If the sun was scaled down to the size of a ping-pong ball we'd need a 20 foot diameter sphere to represent this titanic star. Being only 15 times the sun's mass, Betelgeuse must have an outer atmosphere so tenuous that a starship could likely skirt through unharmed.

Betelgeuse is designated Alpha (α) Orionis but at magnitude +0.4 is actually fainter than Beta (β) or Rigel, which is +0.1. Betelgeuse is slightly variable, however, and on rare and irregular occasions slightly exceeds Rigel. The variations are slow and practically impossible to notice with the eye alone.

Rigel in some ways is even more impressive than Betelgeuse for it ranks as one of the most brilliant stars in the galaxy. Recent measurements give it a diameter 77 times that of the sun and a truly stupendous luminosity 55,000 times greater than "old sol". No star within several thousand light-years is known to exceed Rigel in intrinsic brightness.

Rigel has a whole army of superbright companions, all clustered in the Orion region. Epsilon (ε) is nearly as bright at 40,000 times the sun's luminosity while Saiph (pronounced Saw-EEF) or Kappa (κ) rivals Rigel at 50,000 times solar luminosity. In fact the only bright star in Orion that does not greatly outshine the sun (in absolute terms) is Pi^3 (π) which is only 26 light-years away and three times as bright as the sun. The rest of the first, second and third magnitude stars in the constellation are between 500 and 2,500 light-years away.

The explanation for this concentration of superluminous stars is probably connected with the colossal Orion nebula and the other nebulous patches in the constellation. Nebulae are generally stellar birthplaces as Gerrit Verschuur has pointed out in several of his Stellar Frontiers articles. (See especially "Between the Stars", April 1974.) Orion seems littered with bright, dark, conspicuous and subtle clouds. Many of these are shown in the photo on page 73. The prominent Orion nebula, the Horsehead, and the faint red Barnard's loop that curves down the left side of the constellation are some examples. Although they are not all stellar incubators, the existence of the nebulae and so many young hot stars suggest that the Orion area was recently — and still is — the site of a significant number of star births.

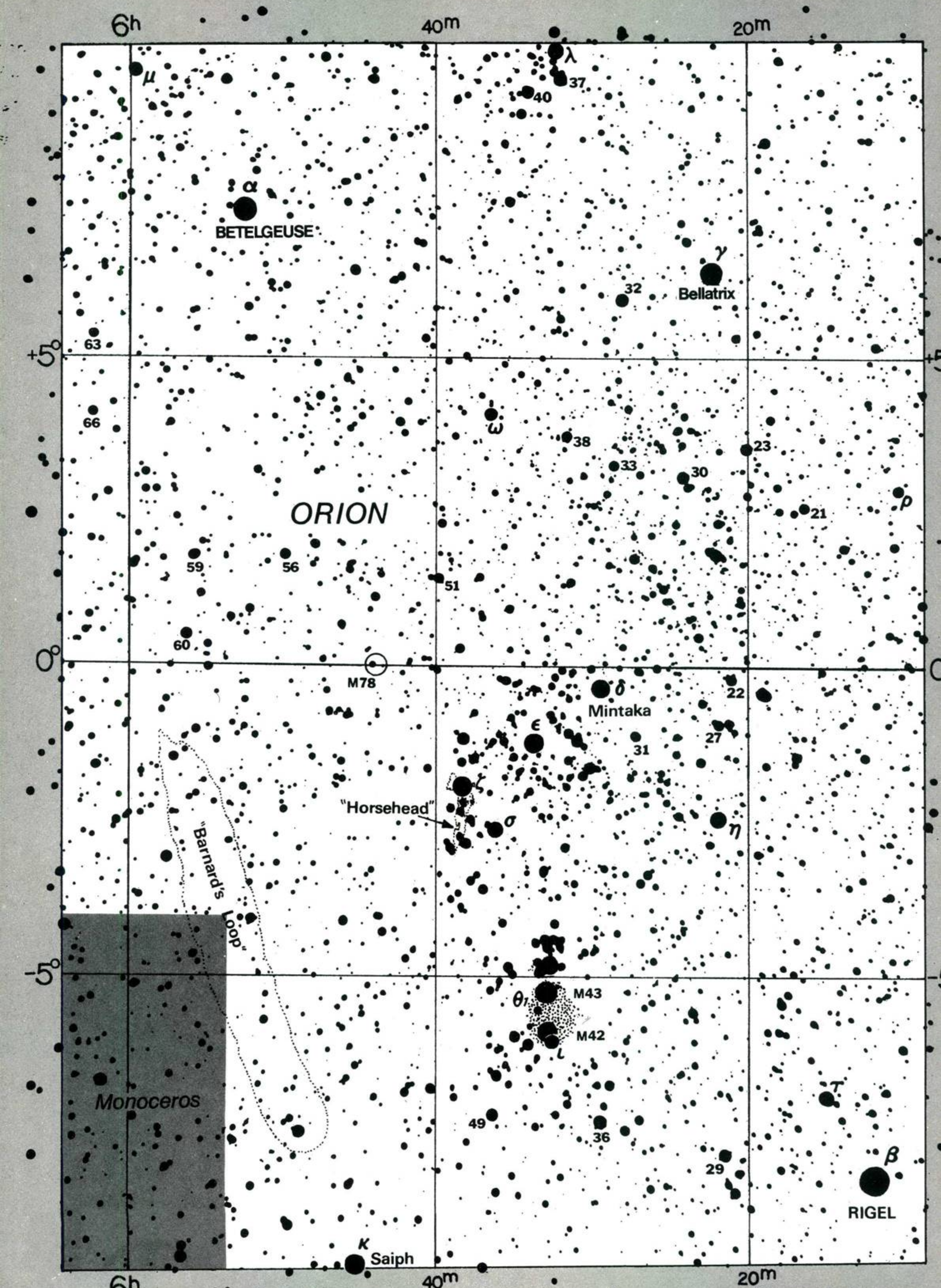
Stars like Rigel cannot be more than a few million years old. They consume their nuclear fuel supplies so rapidly and with such violence that their lifespan is much less than one percent the expected stable lifetime of the sun (11 billion years). Rigel will die in a supernova explosion in less than 10 million years.

Orion contains an enormous number of fascinating objects for binoculars and telescopes. Binoculars should reveal most of what is shown in the photo on page 73 with the exception of some of the nebulosities which record better on film than in the eye. Even so, the Great nebula (described below) is seen as a faint star to the unaided eye and is very conspicuous in binoculars. Because the Orion region is so rich in celestial showpieces we will return to it in a future edition of Star Dome.

Eyepiece Impressions

Orion Nebula (M-42, M-43 and Theta^1 Orionis)

Without question, this brightly glowing cloud of gas and dust is the finest deep sky showpiece visible from northern latitudes, offering an alluring visual adventure for beginning and advanced observers alike. Visible to the unaided eye as a green-


6h
40m
20m
μ
λ
37
40
α
BETELGEUSE
γ
32
Bellatrix
63
+5°
66
ω
38
23
33
30
ρ
21
ORION
59
56
51
60
0°
M78
δ
Mintaka
22
ε
27
31
ζ
"Horsehead"
σ
η
"Barnard's Loop"
-5°
θ1
M43
M42
ι
Monoceros
τ
49
36
β
29
RIGEL
κ
Saiph
6h
40m
20m

Map by Victor Costanzo

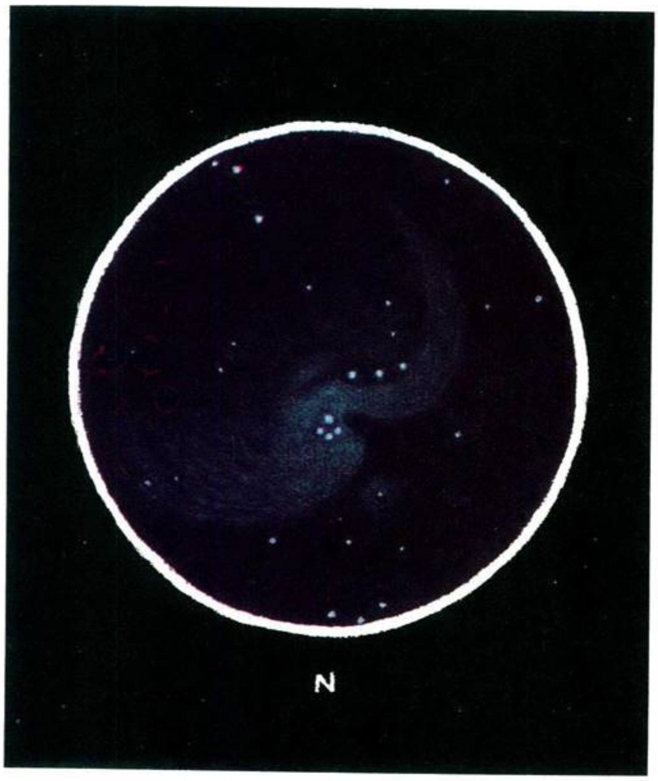
Photograph by John Sanford

ish haze surrounding Theta (θ) in Orion's sword, its grandeur is apparent even in binoculars.

Volumes have been written about this magnificent object and it is still being intensively studied by astronomers today. Within its enormous confines, new stars are believed to be in the process of forming. Indeed, even though its average density is that of a vacuum by earthly standards, it has been estimated that the Orion nebula contains enough matter to form a star cluster. At a distance of some 1,500 light-years, it is one of the nearest objects of its type.

The nebula is excited into fluorescence by the intense radiation of numerous hot blue-white stars embedded within it, making its green hue visible in the smallest of telescopes. This is in fact the only diffuse nebulosity in which color is obvious to the eye. The nebula is so bright that it has actually been seen projected onto a white screen held behind the eyepiece of a 30 inch refractor! Most color photographs show this object as pink or red rather than green due to the fact that the emulsions used are sensitive to wavelengths different than those seen by the eye.

Speaking of photographs, it is possible for a careful observer to trace out much of the extent shown in pictures using four inch and larger telescopes. This is done by slowly sweeping back and forth across the object, following the nebulous wisps and loops to their very extremities where they finally blend into the sky background.



Sketch by James Mullaney

The Orion nebula has a distinct greenish cast in smaller telescopes. This illustration is based on visual observations through a four inch reflector at 45 power. Even in very large telescopes the nebula appears much different from most photographs. Exposures such as this issue's cover reveal details much fainter than the eye can detect — but they also wash out the delicate core that is illustrated here. (The field of view is about one degree.)

Perhaps the most relaxing and effective technique for viewing faint details in this and other nebulae is the so-called "drift method". Here the object is placed just outside the east edge of the field of a low power wide-angle eyepiece. Earth's rotation will then cause the object to slowly drift through the field of view, enabling the eye to pick up an amazing amount of faint detail at the limit of vision. Averted (side) vision should be used, with the eye well dark-adapted.

Surprisingly many observers overlook M-43, the faint detached patch of nebulosity just to the north of M-42. There we find a ninth magnitude star surrounded by gas and dust. Actually M-42 and M-43 are both part of the same object, the apparent bridge of space between them being caused by dark obscuring matter blocking out the light of the nebula beyond. This material is also responsible for the shrinking dark intrusion into the heart of M-42 itself, sometimes called the "Fishmouth".

It is in that area — the heart of the Great Nebula — that we find the amazing multiple star Theta^1 Orionis (known as the Trapezium). (Theta^2 is also in the same field as the Orion nebula — itself a wide double star near Theta^1.) A system of more than a half dozen stars, the four brightest (A, B, C and D on the diagram) range from fifth to seventh magnitudes and are easily seen in a two inch refractor. In good seeing, a three inch refractor or four inch reflector will reveal two additional components (E and F), both 11th magnitude. These stars all appear blue-white in color in small apertures, but definite hints of color contrasts are evident in six inch and larger scopes. Some observers have mentioned pale lilac, garnet and reddish tints for these stars.

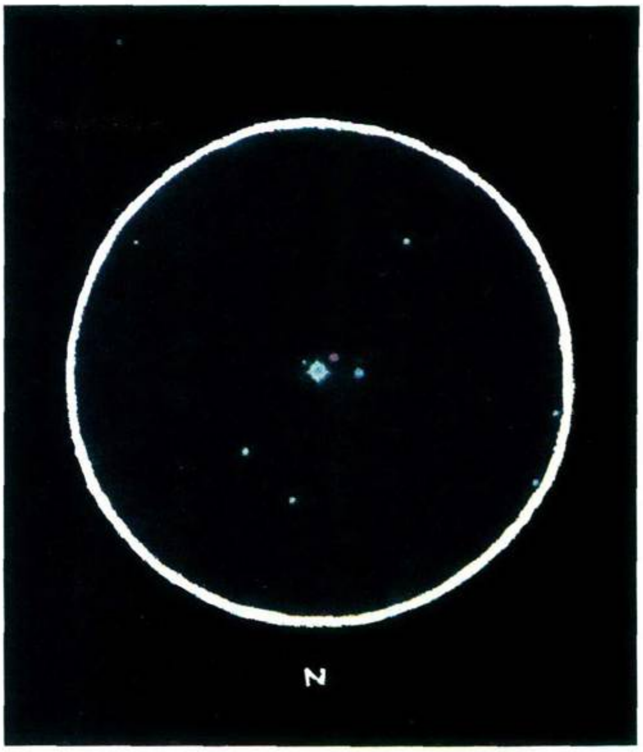
In addition to the six obvious stars, a number of fainter ones have been reported in and near the region of the Trapezium by observers in the past. The most certain ones (G and H — H itself being a double) are 16th magnitude and were discovered visually with the 36 inch refractor at Lick Observatory in California. Notoriously difficult to see, these objects offer a real challenge to the well equipped advanced enthusiast. Can these stars be glimpsed by an observer using a modern 16 inch reflector?

One of the Trapezium stars (B) is known to be an eclipsing binary and other components are suspected — leading us to wonder if we should refer to Theta^1 as a multiple star or a star cluster.

The Orion nebula is one of the few objects of its class that takes high magnifications well — indeed any and all powers seem useful here. At 150 power and higher on eight inch and larger reflectors, the brighter portions of the nebula — especially surrounding the Trapezium — show a complex mottled structure. Sir John Herschel's often quoted description is one of the best and is still quite valid today: "... a curdling liquid, or a surface strewed over with flocks of wool, or the breaking up of a mackerel sky." This last analogy seems especially apt. For best results, those rare nights of both good seeing and transparency are required.

A further point of interest for those who enjoy observing variable stars is that the Orion nebula contains a veritable nest of these stars. There are more than 50 of them brighter than 14th magnitude at maximum, most of which appear red in color in contrast to the green nebulosity. A number of these can be followed with a three inch refractor and nearly all are within range of a good 10 inch reflector.

The boundless wonder and delight of this beautiful interstellar cloud of gas and dust can easily keep you at the eyepiece half the night. As you gaze at it, perhaps you too will join the philospher who questioned if such glories as these were ever meant for the eyes and mind of man.

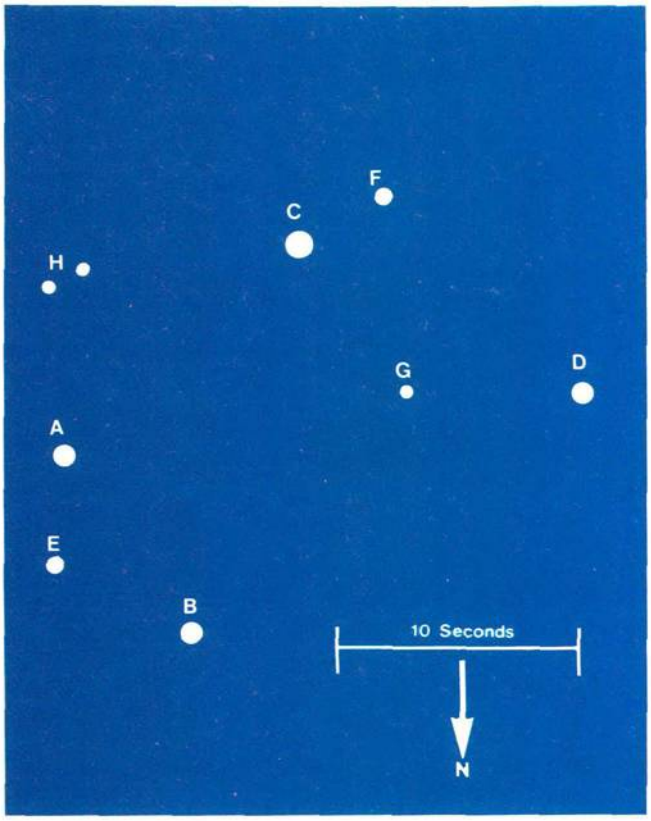


Sketch by James Mullaney

The beautiful telescopic triple star Sigma Orionis is a multiple star system of widely different colored suns. This sketch illustrates the view through a four inch reflector at 125 power. The field of view is about 20 minutes of arc across.

Sigma (σ) Orionis

Visible to the unaided eye just south of Zeta in Orion's belt, this bright and colorful multiple star is easily found and presents a striking spectacle in any telescope.



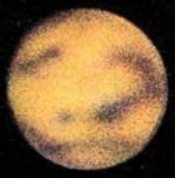
The multiple star Theta Orionis is located at the core of the Orion nebula. The four main stars can be seen in the smallest telescopes but the others require larger instruments. The intermingling nebulosity and density of stars in this area make it one of the finest telescopic views in the entire sky.

Sigma consists of a fourth magnitude cream colored primary, with 7.2 magnitude reddish-purple and 6.5 magnitude blue-white companions at distances of 13 and 42 seconds of arc respectively. In addition, there are at least three other members of this system — only one of which is of interest to the visual observer. This is a 10th magnitude grayish star, about 11 seconds from Sigma (thus the designation "multiple" star rather than "double" or "triple" — the former term generally being used where there are two or more companions).

The three brighter stars are obvious in 2.4 inch and 3 inch refractors. However, the 10th magnitude component may prove difficult in anything less than a four inch, and is sometimes invisible due to the poor seeing that often accompanies the dark transparent skies of winter. As a result, many observers view Sigma as triple rather than multiple.

Of the remaining two components, one is a close spectroscopic object and the other a sixth magnitude star separated by less than 0.3 seconds from the primary. Both are well beyond the reach of amateur instruments. Sigma therefore presents a fascinating example of a stellar family with both visible and invisible members all moving through space together. In the same field with Sigma, a little to the west, is the coarse triple star Struve 761 adding the beauty of the scene.

Planet Finder



Ⓐ Mercury

Feb.	1
R.A.	$21^{h}45^{m}$
Dec.	-10°57'
Mag.	+1.2

Ⓑ Mercury

Feb.	15
R.A.	$20^{h}51^{m}$
Dec.	-14°20'
Mag.	+1.3

Ⓜ Mars

Feb.	1	15
R.A.	$18^{h}35^{m}$	$19^{h}21^{m}$
Dec.	-23°45'	-22°52'
Mag.	+1.6	+1.5

Ⓒ Cer

Feb.	1	15
R.A.	$23^{h}50^{m}$	$0^{h}0$
Dec.	-10°02'	-7°
Mag.	+9.8	+10

Ⓝ Neptu

Feb.	15
R.A.	$16^{h}4$
Dec.	-20°
Mag.	+7.7

SUN

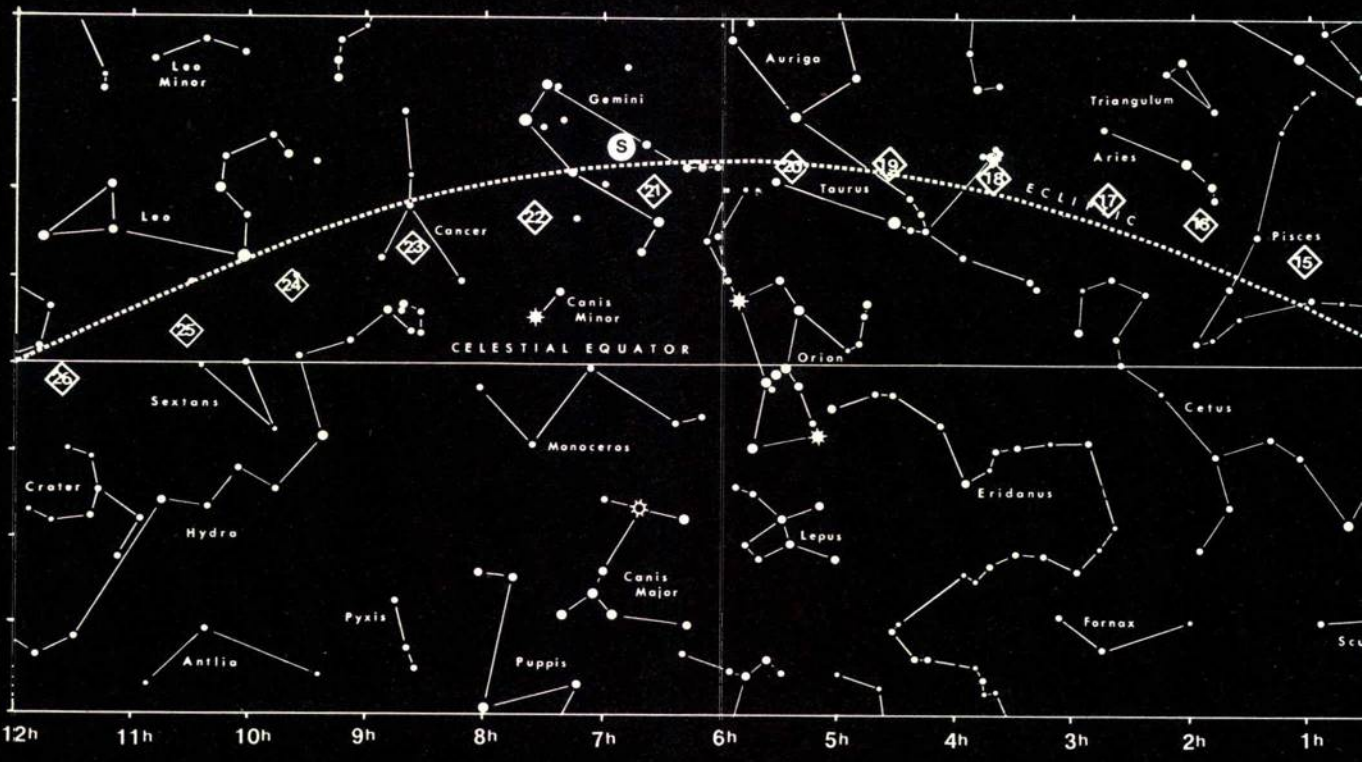
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

Feb.	1	15
R.A.	$6^{h}57^{m}$	$6^{h}54^{m}$
Dec.	+22°25'	+22°32'
Mag.	-0.1	0.0

Ⓤ Uranus

Feb.	15
R.A.	$14^{h}07^{m}$
Dec.	-12°25'
Mag.	+5.8


Leo Minor
Gemini
Auriga
Triangulum
Aries
S
Taurus
ECLI IC
Leo
Cancer
Pisces
15
16
17
18
19
20
21
22
23
24
25
26
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Cetus
Monoceros
Crater
Eridanus
Hydra
Lepus
Canis Major
Pyxis
Fornax
Antlia
Puppis
Sc
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

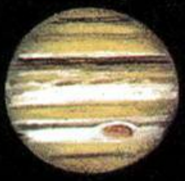
Map by Raymond G. Coutchie

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

February 1975

Vesta

eb.	1	15
.A.	$19^{h}49^{m}$	$20^{h}20^{m}$
ec.	-21°26'	-20°18'
ag.	+9.1	+9.1



Ⓙ Jupiter

Feb.	1	15
R.A.	$23^{h}23^{m}$	$23^{h}34^{m}$
Dec.	-5°08'	-3°53'
Mag.	-1.7	-1.6

Ⓨ Venus

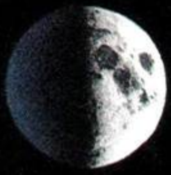
Feb.	1
R.A.	$22^{h}23^{m}$
Dec.	-11°40'
Mag.	-3.4

Ⓩ Venus

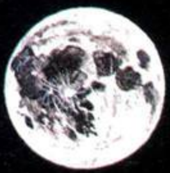
Feb.	15
R.A.	$23^{h}28^{m}$
Dec.	-4°48'
Mag.	-3.4

Pluto

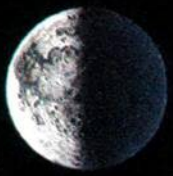
eb.	15
.A.	$12^{h}59^{m}$
ec.	+12°00'
ag.	+14.3



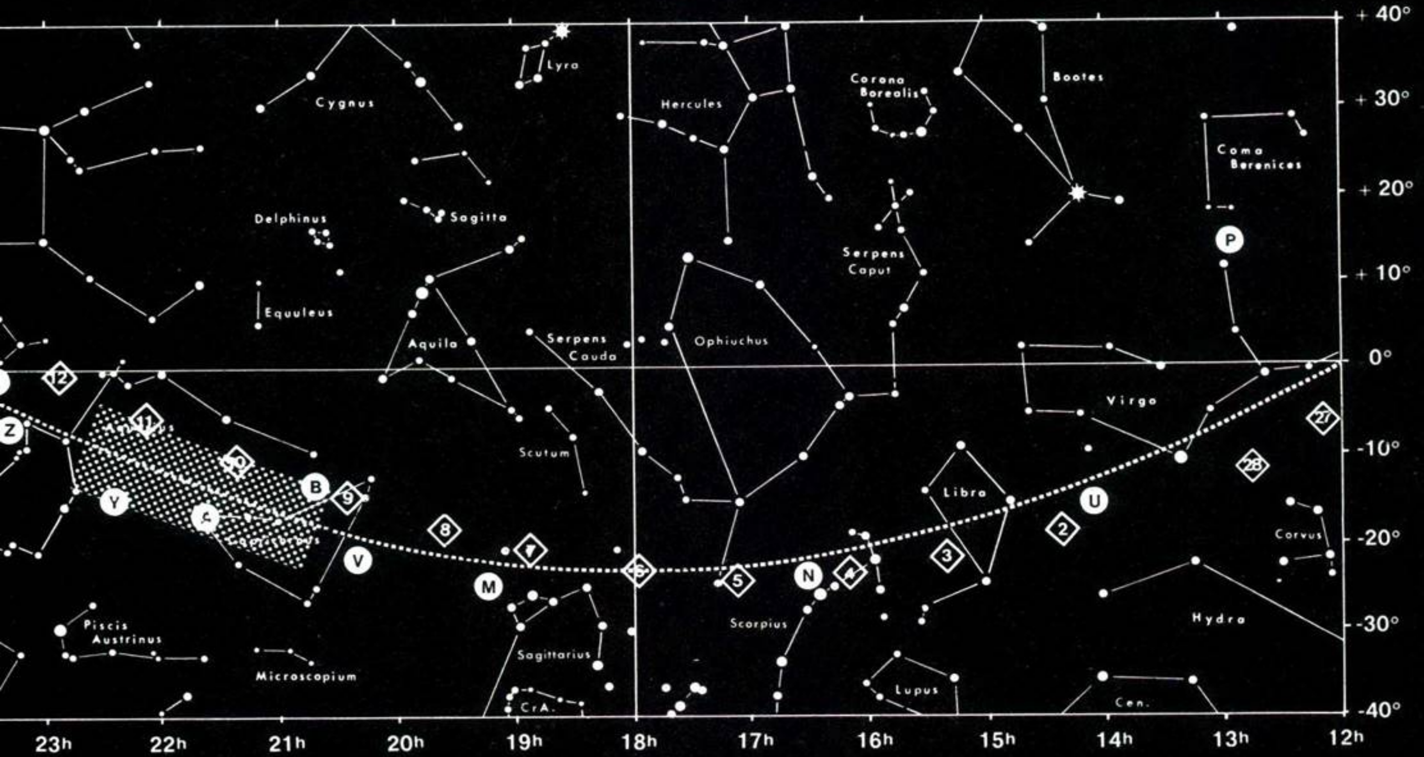
First Quarter
Feb. 19



Full Moon
Feb. 25



Last Quarter
Feb. 3


Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Serpens Caput
Virgo
Scutum
Libra
Corvus
Capricornus
Sagittarius
Scorpius
Hydra
Piscis Austrinus
Microscopium
Lupus
CrA.
Cen.
P
Z
Y
B
V
M
N
U
12
11
10
9
8
7
6
5
4
3
2
28
27
+ 40°
+ 30°
+ 20°
+ 10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h

Artwork by Victor Costanzo

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

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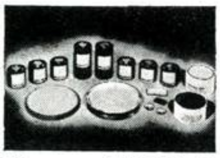

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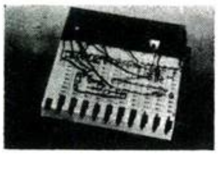

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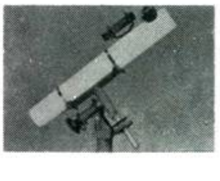

Great for astrophotography! Features 48" F.L. f/8 Pyrex (R) parabolic mirror acc. to 1/4 wave; massive equatorial mount (usually found only on 8"); precision 2" I.D. heavy duty rack & pinion focusing mount capable of supporting any camera w/o special holder. Incl: electric clock drive w/ manual slow-motion control, deluxe widefield 6X finder w/ crossline reticle; 3 eyepieces: 1", 48X Kellner; 1/4" 192X Ramsden; Barlow to dbl & triple power. 24" wobble-free metal base.

No. 85,248K (SHP. WT. 200 LB) . . . . $499.00 FOB

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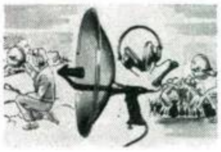
PRO ELECTRONIC SOUND CATCHER



Parabolic mike w/ 18-3/4" reflecting shield & 2 I.C.'s in amplifier magnifies signals 100X that of omni-directional mikes. Catch a songbird 1/2 mile off; QB's huddle strategy; sounds never before heard. Super directivity gives highest signal to noise ratio poss. Safe: auto. cuts off ear damaging noises. Earphones, tape recorder output, tripod socket. Req. two 9v trans. batt. (not incl).

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BIG EAR "TOY" MODEL #80,176K . . . . $32.25 Ppd.

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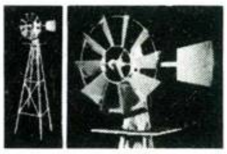
AUTHENTIC SCALED WINDMILLS



Real-thing replicas show wind direction, wheel silently revolves on ball bearings. Give your grounds unique rural charm! Great centerpiece for planter, flowers. Use to hold yard light, house number, sign or as mailbox. For school, a fine "energy crisis" science project — does everything but pump water. Heavy gauge steel, durable outdoor finish; aluminum color w/red trim.

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